



Enhancing Mathematics Teacher Educators' Technological Pedagogical
Content Knowledge through Collaborative Professional Development:

Ethiopia

by

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Doctor of Philosophy

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Declaration of Originality

This thesis contains no material, which has been accepted, for a degree or diploma by a University or any other institution, except by way of background information and duly acknowledged in the thesis. To the best of my knowledge and belief, it contains no material previously published or written by another person except where due acknowledgement is made in the text of the thesis.

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Statement of Ethical Conduct

“The research associated with this thesis abides by the international and Australian codes on human and animal experimentation, the guidelines by the Australian Government's Office of the Gene Technology Regulator and the rulings of the Safety, Ethics and Institutional Biosafety Committees of the University.”

Abstract

This study documented the design, development and refinement of a professional development program, which improved teacher educators' knowledge, to facilitate their effective use of technology in teaching mathematics. The study was conducted in two Ethiopian Colleges of Teacher Education. It involved 16 mathematics teacher educators, four Information Communication Technology coordinators, and 247 elementary pre-service mathematics teachers. The study was undertaken across three phases. The first phase comprised a contextual and problem analysis and development of a conceptual framework based on a literature review that provided the basis to design the first professional development program prototype. The second phase involved setting out design guidelines and optimising the professional development program prototype through two cycles of design, formative refinement and revision. The last phase of the study was an evaluation of the extent to which the professional development program that took place over 5 months had met its objectives. The study used a mixed methods approach, which involved the collection of both quantitative and qualitative data informed by an educational design research methodology. Data were collected using questionnaires, observation checklists, semi-structured interviews, focus group discussions and professional learning workshops.

One of the findings of the study in the first phase showed that the teacher educators believed they had little knowledge of technology and its effective use in their teaching of mathematics, and that this was a major barrier resulting in limited technology use in their teaching. The first phase of the study informed the design of the professional development program in the second phase of the study.

The designed professional development program was characterised by its focus on the pedagogical use of technology, provision of exemplar material, the use of available and web-based technologies, the formation of teams, support from Information Communication Technology (ICT) coordinators, and an emphasis on informality in the professional development arrangements. The results in the third phase of the study showed that the professional development program contributed to increased use of technology by the mathematics teacher educators and their pre-service teachers. The teacher educators' perceived knowledge of how to use and integrate technology teaching practices in their teaching of mathematics was improved and this was associated with positive changes in their effective technology integrated mathematics teaching as evidenced by the classroom observations.

Dedication

This thesis is dedicated to my father, Tekeher Getenet, who was everything for my family and me. You left fingerprints of grace on my lives. You will be in my heart forever!

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Definition of Terms

Term	Definition used in the study
Pre-service Teachers	Prospective teachers of primary school (Ages 7 -14) mathematics
Teacher Educators	Teachers of pre-service mathematics teachers
Mathematics Education	The practice of teaching and learning mathematics
Information Communication Technology (ICT)	Refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc.
Technologies	In this thesis technology is taken to refer to ICT as defined above
Professional Development	Nurturing of learning communities within which teacher educators try new ideas, reflect on outcomes, and co-construct knowledge about teaching and learning.
College of Teacher Education	Institutions that prepare pre-service teachers of primary schools

List of Acronyms

Colleges of Teacher Education	CTEs
Common Content Knowledge	CCK
Content Knowledge	CK
Educational Design Research	EDR
Ethiopian Central Statistical Agency	CSA
General Education Quality Assurance and Examination Agency	GEQAEA
Higher Diploma Program	HDP
Horizon Content Knowledge	HCK
Information Communication Technology	ICT
Knowledge of Content and Curriculum	KCC
Knowledge of Content and Students	KCS
Knowledge of Content and Teaching	KCT
Mathematical Knowledge for Teaching	MKT
Ministry of Education	MOE
National Agency for Examination	NAE
National Learning Assessment	NLA
Pedagogical Content Knowledge	PCK
Pedagogical Knowledge	PK
Professional Development	PD
Southern Africa Consortium for Monitoring Educational Quality	SACMEQ
Specialised Content Knowledge	SCK
Specialised Mathematics Knowledge	SMK

Specialised Pedagogical Knowledge	SPK
Specialised Pedagogical Mathematics Knowledge	SPMK
Specialised Technological and Mathematical Pedagogical Knowledge	STAMPK
Specialised Technological Mathematics Knowledge	STMK
Specialised Technological Pedagogical Knowledge	STPK
Statistical Package for Social Science	SPSS
Technical Vocational Education and Training Colleges	TVETCs
Technological Content Knowledge	TCK
Technological Knowledge	TK
Technological Pedagogical Content Knowledge	TPACK
Technological Pedagogical Knowledge	TPK
Technology Proficiency Self Assessment	TPSA
Transitional Government of Ethiopia	TGE
United Nations Development Program	UNDP

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Chapter 1 Introduction

This chapter introduces the overall design of the study. It also introduces the research background of this study, which includes the use of technology in teaching, particularly mathematics teaching and the knowledge required to integrate technology in teaching. The chapter further presents the research questions together with the overall objective of the study. The significance of the study is also outlined in this chapter. The research methodology is introduced, including data collection methods and tools for data analysis along with ethical considerations and an overview of the structure of the thesis. This chapter begins by introducing how the current study was initiated.

1.1.The Researcher's Note

This study was conducted to design, develop and evaluate a job embedded Professional Development (PD) program that could support mathematics teacher educators to integrate technology in their teaching at two Ethiopian Colleges of Teacher Education (CTEs). The initial inspiration for this study arose from the researcher's own teaching and learning experience in schools and at a Teacher Education University in Ethiopia. The researcher first graduated in mathematics education at Bachelor degree level and worked as a secondary school mathematics teacher for 2 years. Later, he graduated in Mathematics Education at Masters level and took the opportunity to be a University teacher educator for 4 years. In 2010, the researcher moved to the Netherlands to study for a Master's degree in Educational Science and Technology at the University of Twente where technologies were used intensively in teaching. The researcher had always aspired to use technology in teaching mathematics in schools and University. The experience gained at the University of Twente inspired him to conduct the Master's thesis

research as part of the study in Educational Science and Technology on the topic “use of technology in teaching in Ethiopian schools.” Conducting this study at Ethiopian school level unlocked an opportunity to approach the issue in different ways. Most previous studies involved primary and secondary school teachers; however, little attention was given to the teacher educators who prepared secondary and primary school teachers. Particularly, because technology is a recent innovation and not mature in most developing countries’ schools, including those in Ethiopia, the researcher decided to study the issue at CTEs from teacher educators’ perspectives and practice. The researcher believed that doing research at a teacher education institution amounted to beginning to solve from its roots the problem of ineffective and insufficient use of technology in Ethiopian schools.

After reviewing relevant literature on the use of technology by mathematics teacher educators with a view to designing a context based PD program, significant gaps were found that could be explored. At the beginning of 2012, the PhD journey was started with the thesis topic “Enhancing Mathematics Teacher Educators' Technological Pedagogical Content Knowledge through Collaborative Professional Development: Ethiopia.”

1.2. Research Background

Technologies have been in use for many years for the purpose of classroom instruction. Note that the term ‘technology’ is used in this thesis, unless ‘Information Communication Technology (ICT)’ is used by those authors of studies cited. Studies have shown that the use of technology as a learning tool, within meaningful learning contexts can lead to significant educational and pedagogical changes in the schools and bring major benefits to both learners and teachers (e.g., Ayub, Mokhtar, Luan, & Tarmizi, 2010; Su, 2008; ten Brummelhuis & Kuiper,

2008; Voogt, 2008). As a result, university, college and school teachers are integrating technology into teaching to achieve higher learning outcomes. Using various technologies, in teaching mathematics can enhance teachers' instruction and students' active engagement. According to Chee, Horani, and Daniel (2005), ICT based learning environments in mathematics education provide opportunities for active learning, enable students to perform at higher cognitive levels, support constructive learning, and promote scientific inquiry and conceptual change. As a result, integrating technology in mathematics learning is receiving global attention.

The government of Ethiopia has tried to take advantage of technology to increase the quality of education. To facilitate the integration of technology tools into teaching, the government has formulated a number of technology implementation initiatives in education. Hare (2007) indicated that these initiatives focus on deploying educational technologies within the universities, colleges, schools, and research institutions as a way to widen access to education, for supporting teaching, and to facilitate the delivery of improved quality of education at all levels. In spite of the government's encouragement in its policy documents for teachers at all levels to use ICT (Ministry of Education [MOE], 1994), teachers in higher education seldom integrate the available technologies in their teaching (e.g., Hare, 2007). Similarly, mathematics teacher educators in the Colleges of Teacher Education (CTEs) tend not to use technology in their teaching. This situation implies that the pre-service teachers, who have not seen its use in teaching, are likely to be less prepared to use technology in their own teaching.

A variety of factors is most likely responsible for this. A number of literature reviews have focused on difficulties of integrating technology into teaching and have cited the lack of technological resources as the most frequently mentioned barrier, followed by teachers' lack of

technological knowledge (e.g., Chai, Koh, & Tsai, 2010; Donnelly, McGarr, & O'Reilly, 2011). Unwin (2005) indicated that computer laboratories in educational institutions across Africa are underutilised. Whilst there are some notable exceptions to this generalisation, computer laboratories in schools and higher educational institutions stand idle for much of the time (Unwin, 2005). As more classrooms become technology rich environments, it is less likely that teachers will perceive the lack of technological resources as a barrier to effective technology integration. Nevertheless, increased access to ICT resources does not guarantee increased rates of effective integration of ICT (Etmer, 2005; Hew & Brush, 2007). The other major barrier to effective technology integration is teachers' knowledge of technology and pedagogy. This is essentially the idea of Pedagogical Content Knowledge coined by Shulman (1986) and extended into the domain of teaching with technology by Mishra and Koehler (2006) where it is termed Technological Pedagogical Content Knowledge (TPACK). TPACK is likely to take the place of lack of technology resources as the main determinant of the extent to which ICT is integrated into teaching (Niess, 2011) because teaching with technology requires its development.

Mishra and Koehler (2006) described TPACK (which is discussed further in Chapter 3 in Section 3.2.2.1) as the knowledge of how to facilitate students' learning of specific content through appropriate pedagogy and technology. It requires teachers to reflect on the critical relationships between content, technology and pedagogy (Koehler & Mishra, 2009; Niess et al., 2009). According to Jimoyiannis (2010) and Koehler and Mishra (2009), however, the ability of teachers to establish the relationship between content, pedagogy and technology depends largely on the way that they have been taught to integrate technology into teaching and the way these components are treated in PD programs. A number of studies have suggested a range of PD

program strategies to support teachers' effort to integrate technology in their teaching. Most encourage a PD program with characteristics of collaborative engagement, incorporating practices, relevant to the classroom and school context and practically tested in the classroom (e.g., Borko, 2004; Hea-Jin, 2007; Rogers et al., 2007; Zaslavsky & Leikin, 2004). Grossman (1990), and Putnam and Borko (1997) all regarded PD programs as a tool for the growth of teachers' content, pedagogical knowledge, and skills to enhance learning.

1.3. Objective and the Research Questions of the Study

This study documented the design, development and refinement of a job embedded PD program that supported mathematics teacher educators to integrate technology into teaching in two CTE in Ethiopia. It examined the current practices of mathematics teacher educators' technology integrated teaching practices and their pre-service teachers' views of technology integrated teaching. It also investigated the factors influencing teacher educators' practices of technology integrated teaching. The study used a mixed method research approach whereby the data were collected using questionnaires, an observation checklist, interviews and focus group discussions (including workshops). The following research questions focussed the overall objective of the study:

1. What competencies do teacher educators currently have in relation to integrating technology into the teaching of mathematics education?

This research question focused on Ethiopian teacher educators' current competencies in relation to technology integrated teaching and provided information about the context in which an appropriate PD program needed to be delivered. Teacher educators' competencies were

identified before the PD program was designed, using a questionnaire, interviews and observation sessions.

2. What are the factors that influence teacher educators' integration of technology into teaching?

Identification of hindering and facilitating factors in teacher educators' technology integrated teaching practice was the focus of Research Question 2. This step supported the design of a PD program, by taking into account the factors influencing teacher educators' technology integrated teaching that were identified using questionnaires, focus group discussion, and interview.

3. How might an intervention support the development of teacher educators' skill in relation to integrating technology into teaching?

This research question related to characteristics of an intervention in the form of a PD program that fits with the particular contexts and positively influences teacher educators' technology integrated teaching practices. This research question was addressed using a review of existing literature, a contextual analysis, and questionnaires and interviews with teacher educators, pre-service teachers, and ICT coordinators.

4. What competencies can teacher educators demonstrate in relation to integrating technology into teaching after participating in a PD program?

The impact on teacher educators' technology integrated teaching resulting from the PD program was the focus of Research Question 4. This research question considered the cumulative effect of the first three research questions by comparing teacher educators' initial technology integrated teaching practice identified based on Research Question 1 and the new practice

identified after teacher educators' participated in a PD program identified in Research Question 3.

These research questions were addressed across the three phases of the study, namely: Phase 1: context analysis, Phase 2: design and improvement of a PD program and Phase 3: assessment and evaluation of the impacts of the PD program. The relationship between research questions and the phases of the study is shown in Figure 1.1.

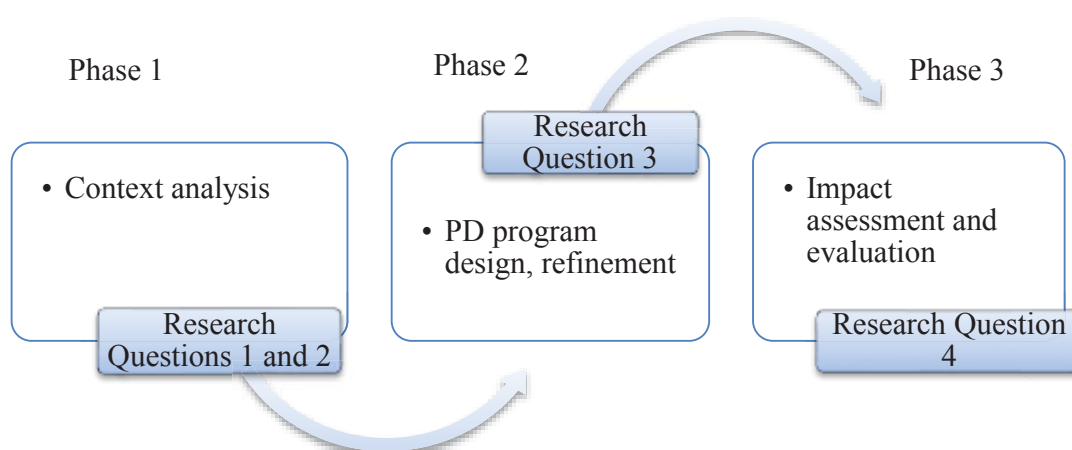


Figure 1. 1. The link between the research questions and phases of the research.

As shown in Figure 1.1, the research questions were formulated to address the context of the research site (including participants' competencies with the use of technology in teaching and relevant features of the CTEs contexts). The analysis of the context informed the design and development of a PD program that supported teacher educators to integrate technology in their teaching. Finally, an assessment and evaluation were needed to understand the impact of the PD program on teacher educators' practice in relation to integrating technology in their teaching. In looking for an approach that addressed these activities systematically, Educational Design Research (EDR) was considered appropriate. EDR involves inquiry focused on understanding

the responses that a program generates (McKenney & Reeves, 2012). EDR supports the rigorous analysis of a learning problem leading to quite specific ideas for a PD program relevant to the research site (Walker, 2006). McKenney and Reeves (2012) also indicated that EDR can be conducted for creating a PD program and to solve context based problems in practice.

1.4. Significance of the Study

This study was intended to enhance the capacity of mathematics teacher educators to use technology in their teaching in the context of mathematics through the design, implementation and evaluation of a PD program. The study, therefore, can contribute to the use of technology in teaching mathematics in the context of the two CTEs (to provide anonymity, these were called College 1 and College 2) in particular and in terms of knowledge of mathematics education in general. This study can serve as reference material for the development of policy and provides PD program materials in the field of integrating technology in the teaching and learning process in general and in the area of mathematics education in particular. Its emphasis on developing countries addresses a gap in the literature, as there have been few studies in the context. The study aimed to introduce a culture of well planned in-service PD programs to the Ethiopian teacher education system and support that may be transferable to similar contexts. It was intended to contribute to the development of favourable attitudes towards the PD program activities among teacher educators. More specifically, the study results can help Ethiopian mathematics teacher educators improve their technology integrated teaching practices, thereby improving their teaching performance, and enhancing pre-service teachers' learning. Most significantly, this study adds to the knowledge bases linking mathematics education, PD programs, and technology integration in teacher education. For example, the study developed a

mathematics specific version of the TPACK framework called Specialised Technological and Mathematics Pedagogical Knowledge (STAMPK). In this new framework, the study showed how a particular conception of the knowledge required teaching mathematics could be integrated with the TPACK framework as the basis for understanding technology integrated mathematics teaching. Moreover, the study encourages other professionals in the field to carry out further studies on this same issue and other related topics, for example, the use of technology in other subject areas of teacher education. The potential educational benefits identified in the study and implications made are transferable to other similar CTEs, which intend to provide future PD programs in this area.

1.5. Research Methodology

The study used a mixed method approach, which involved both quantitative and qualitative data collection methods. Moreover, the study used an EDR approach, particularly EDR through intervention described by McKenney and Reeves (2012) in which the inquiry is focused on understanding the responses that a specific PD program process give use to.

1.6. Ethical Considerations

Tasmanian Social Sciences Human Research Ethics Committee approved the ethics application of this study with ethics reference number H1236 (see Appendix A). The ethics process provided the basic principles and guidelines, which helped the researcher to uphold the ethical issues that he valued in terms of the design and execution of the research. As suggested by Lutabingwa and Nethonzhe (2006) to consider three ethical issue aspects in conducting social research were considered in this study: the ethics of data collection and analysis; the ethics of the

treatment of participants; and the ethics of responsibility to the society. These issues were kept in mind by the researcher throughout the data collection, analysis, and interpretation of results.

In each aspect of the study process, the researcher ensured that all participants were involved based on their full consent. Written consent was obtained from all participants (teacher educators, pre-service teachers and ICT coordinators) who participated in one or more of the activities, which includes questionnaires, interviews, focus group discussions (including workshops), and classroom observations.

Feedback to participating teacher educators and ICT coordinators was provided in different forms and on various occasions throughout the study. An evaluation workshop was conducted to evaluate the overall process and the impact of the PD program. This included gathering teacher educators' reflection and feedback. Teacher educators and ICT coordinators were encouraged to reflect on the overall activities of the PD program process as an opportunity to learn from each other and obtain feedback on their technology integrated teaching practices and PD program participation to inform future improvements. In addition, the summary of the draft report was forwarded to the teacher educators and ICT coordinators as part of the feedback for participants; this was an opportunity for them to receive feedback on their technology integrated mathematics teaching practices.

1.7. Structure of the Thesis

This thesis is organised in seven chapters. This chapter, Chapter 1, has introduced the background of the study along with the research questions and outlined the overall aims of the study together with its significance. The research questions were introduced and the overall design and procedure of the study were outlined in this chapter. Chapter 2 provides the general

context of the Ethiopian education system, CTEs, and use of technologies in teaching in that context. The literature related to the study is reviewed in Chapter 3. In that chapter, the gaps are identified and ways in which the current study addressed them are described. Chapter 4 describes the method and the procedures used in the study. Chapter 5 reports the results of the study in three main sections. The first of these discusses the results of analysis of context aimed at informing the design of context based PD program guidelines (Section 5.1). Section 5.2 of Chapter 5 reports on the outcomes of the improvement and evaluation process of the PD program. Evaluation of the final PD program is the focus of the third section, Section 5.3. The results reported in Chapter 5 are discussed in Chapter 6, and Chapter 7 presents the conclusions and outlines the main implications of the study.

1.8. Chapter Summary

This chapter has introduced the study and the structure of the thesis. The objective and questions of the study were introduced, followed by the significance of this study. Based on the theoretical consideration of the research, the methodology used in the study was introduced which is underpinned by mixed method approach through an EDR approach. Lastly, this chapter has introduced the ethical considerations and the structure of the thesis.

The following chapter will provide an overview of the Ethiopian education system in relation to mathematics education, and technology use in teaching and teacher education system. The chapter will also discuss the quality of mathematics education in Ethiopia along with PD program trends of Ethiopian higher education teachers. The chapter will thus provide crucial information about the context in which the study was conducted.

Chapter 2 Context

The previous chapter provided an overview of the study, including the background its objectives and the research questions that guided the study, as well as its significance. The chapter also provided an overview of the research methodology used in the study. In later sections, Chapter 1 described ethical considerations, structure and overall design of the study. This chapter describes the context in which the study was conducted. The chapter comprises six sections. Section 2.1 describes the educational system in Ethiopia; Section 2.2 describes the quality of mathematics education in the Ethiopian context, Section 2.3 explains teacher education systems in Ethiopia, and Section 2.4 describes trends in the practice of technology use in teaching and technology policy status in Ethiopia. Finally, trends in Professional Development (PD) programs related to teacher education in Ethiopia are described in Section 2.5 followed by a summary of the chapter in Section 2.6.

2.1. The Education System in Ethiopia

Ethiopia is an Eastern African country located in the horn of Africa just West of Somalia as shown in Figure 2.1. It covers an area of 1.25 million square kilometres and has a population of 86,613,986 of which 43,715,971 are males and 42,898,015 are females as reported by Ethiopian Central Statistical Agency (CSA) (CSA, 2012). Currently, Ethiopia is the second most populous country in Africa, after Nigeria. The young and growing population has consequences for the education sector. In particular, with educational expansion, Ethiopia has an ambitious Education Sector Development Program with the major objective of improving the quality, relevance, equity and efficiency of education, and expanding access.



Figure 2. 1. Map of Ethiopia (Source: <http://i.infoplease.com/images/methiop.gif>).

In Ethiopia, education is considered the main vehicle to transform the country's economic growth. As a result, the Ethiopian government gives due emphasis to the education system (Ministry of Education [MOE], 2010, Ministry of Finance and Economic Development, 2010). Many scholars welcomed the issue of the present Education and Training Policy in 1994 because it addressed equity, efficiency, quality, and access to education. In this policy, the country's education was envisioned as characterised by democracy, professionalism, effectiveness, efficiency, coordination, and decentralisation. The national Education and Training Policy which accompanied the framework launched the first 5 year Education Sector Development Program in 1997 as part of a 20 year education sector plan (Kassaye, 2005). The education policy provides guidelines about the structure of the school system and other aspects of the education system.

The educational system is organised in accordance with the Federal Government's state structure. The country is divided into nine regional states and two city administrations.

Accordingly, each of these has its bureau of education responsible for the administration and management of the education system in that jurisdiction. Within each of these exists a network management structure involving subdivisions called zonal educational departments and woreda education offices. The latter is the smallest educational authority responsible for primary and secondary schools in its territory. Theoretically, each of the national regional state education bureaus is both administratively and financially responsible for education in its region, but with a substantial subsidy from the federal government for general education and the Technical Vocational Education and Training Colleges (TVETCs) as well as for Colleges of Teacher Education (CTEs) that operate in their respective states. Universities are, however, the mandate of the federal MOE. Each regional government manages TVETCs and CTEs. Figure 2.2 indicates the management structure of education institutions in Ethiopia.

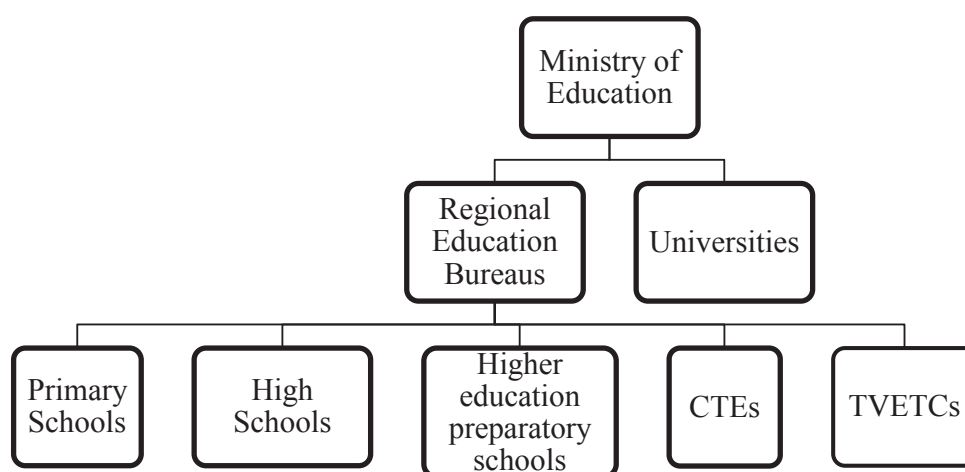


Figure 2. 2. Management of education in Ethiopia.

As indicated in Figure 2.2, the Federal government has direct responsibility for universities while the respective regional education bureaus manage the other education sectors.

The Ethiopian education system encompasses formal and non-formal education. Non-formal education covers primary education provided to adults who have dropped out and returned for schooling, or late beginners. The formal education program is divided into kindergarten, general, TVET and tertiary education programs (MOE, 1994).

In Ethiopian schools, education is divided into an 8+4 structure: 8 years of primary education divided into two cycles, each having 4 years duration, and 4 years of secondary education divided into another two cycles, each having 2 or 3 years duration. In total, there are 10 years of general education consisting of 8 years of primary education and 2 years of general secondary education (Grades 9 and 10). This is followed by 2 years of TVETC, CTE or a university preparatory program (the second cycle of secondary education (Grades 11 and 12) which prepares students for continuing to higher education. Primary education comprises Grades 1 through 4 of basic education and the second cycle of Grades 5 through 8 general primary education (MOE, 1994). Student progression from primary school level to the next and subsequent levels is based on a system of national examinations at Grades 8, 10 and 12. The summary of the structure of the education system is shown in Figure 2.3.

After finishing general secondary school (Grade 10), students have two possibilities for further study, depending on their national examination results at that point. Students who scored better results compared with their colleagues will join university preparatory school (Grades 11 and 12) and the remaining joining either CTEs or TVETCs. TVETCs were designed to the needs of the labour market for a competent, motivated and adaptable workforce capable of driving economic growth and development (Killian, Tendayi, & Augustine, 2009). CTEs prepare first and second cycle primary school teachers. These teachers specialise in a particular subject.

Possible specialisations include mathematics, physics, biology or chemistry. Children are entitled to free education up to Grade 10, after which a tuition fee is applied. The tuition fee system at Grades 11 and 12, however, is not yet established and hence it is free.

<i>Age</i>	<i>Grade/year</i>				
23	V				<i>Post Graduate Studies</i>
22	IV				
21	III	Year Level	3		<i>University Study</i>
20	II	Year Level	2		
19	I	Year Level	1		
19		Level	3		<i>Teacher Education Colleges or Technical Vocation Education Colleges</i>
18	12 or	Level	2		
17	11 or	Level	1		
16	10				<i>General Secondary School</i>
15	9				
14	8				
13	7				<i>Second Cycle Primary School</i>
12	6				
10	4				<i>First Cycle Primary School</i>
9	3				
8	2				
7	1				
4 - 6					<i>Kindergarten</i>

Figure 2. 3. Structure of the education system in Ethiopia.

Students learn different subjects at different levels. Mathematics is offered as a separate subject all the way from Grade 1 through general secondary school, and science is offered as environmental science (integrated form) in Grades 1 to 6 and separately as Biology, Chemistry and Physics thereafter.

2.2. Quality of Mathematics Education in Ethiopia

Although mathematics is of paramount importance in the modern scientific and technological world, assessment results indicate that many countries in Africa, including Ethiopia are experiencing a decline in students' participation and performance in mathematics (e.g., Southern Africa Consortium for Monitoring Educational Quality [SACMEQ], 2011; National Agency for Examination [NAE], 2010). In most developing countries, students are performing lower in mathematics compared with other subjects (Murimba, 2005) as indicated in results of standardised measures (i.e., SACMEQ) which are used in some African contexts to assess students' performance in mathematics and other subjects. These studies have indicated that the quality of mathematics in Africa is of serious concern. Both primary and secondary level mathematics education is weak in most African countries as reported by the General Education Quality Assurance and Examination Agency (GEQAEA) and NAE of Ethiopia (GEQAEA, 2008; Murimba, 2005; NAE, 2010). In 2009, 15 Southern African countries participated in the third study for monitoring educational quality conducted by the third SACMEQ. A random sample of 3416 Grade 6 learners from 169 Southern African public schools was tested in reading (literacy) and mathematics (numeracy). The result indicated that the learners performed poorly in mathematics (SACMEQ, 2011). Ethiopia was, however, not included in these studies.

There is evidence that the quality of students' performance in mathematics is inadequate at both primary and secondary schools in Ethiopia. The National Learning Assessment (NLA), conducted every 4 years indicates that students' performance in mathematics is lower compared to other subjects. Ethiopia has carried out three NLAs at the first and second cycles (Grades 4

and 8, ages 10 and 14) of primary education since 2000. For secondary schools (Grades 10 and 12, ages 16 and 18 years), the first NLA was carried out in 2010.

The first NLA of students' achievement in Ethiopia was carried out in 2000 at the end of the first (Grade 4) and second (Grade 8) cycles of a primary school on a sample basis in four subjects including mathematics. The second NLA was carried 4 years later in 2004. The third NLA for Grade 4 and Grade 8 students was then undertaken in 2008 by General Education Quality Assurance and Examination Agency [GEQAEA] (2008). The mean score for Grade 4 students in mathematics was 43.7% in 2008 which is less than the minimum requirement of 50% pass mark from one grade to the next level (MOE, 1994). The MOE assumes an equivalent standard (50%) of test results for NLA and grade progression from test to test. The standard was kept consistent across iterations of the test by item test analysis in order to look at the nature of the items and pick items for future use (NAE, 2010).

The NLA for Grades 10 and 12 students was conducted in 2009. The main purpose of the study was to determine what secondary students knew upon completion of General Secondary Education (Grade 10) and the University preparatory program (Grade 12) in light of the minimum learning competencies set by the MOE for both grades. The percentages of students in Grade 10 who scored 50% (the standard that the ministry set as a pass mark and designated proficient) or more in mathematics was only 14.7% (NAE, 2010).

The results indicated that students were performing below the standard set at both primary and secondary levels in mathematics. These results were unsatisfactory and showed that something needed to be done to improve the teaching and learning of mathematics. Hence, there is a need for improved quality mathematics education at all educational levels. According to

MOE of Ethiopia, for quality education, teachers need to be supported and become familiar with necessary knowledge and pedagogies that can help to diagnose and intervene at the individual student level. There is a need for schools and teachers to be supported through PD programs to extend their use of effective pedagogical techniques to support students' learning and performance (Belihu, 2010; Dufera, 2006). Mathematics teachers are expected to have the necessary content and pedagogical knowledge for effective teaching in the classroom. As a result, efforts have been invested in PD programs for teachers aimed at equipping them with the necessary competencies and skills to make them effective in the classroom. Studies have indicated that teachers' competence demands knowledge and skills related to both content and pedagogical knowledge (e.g., Hsieh et al., 2011; Park, Jang, Chen, & Jung, 2011; Schmidt et al., 2008; Tatto & Senk, 2011). These types of knowledge for teaching are discussed in detail in Chapter 3, Section 3.3. The use of technology at all educational levels in teaching is also cited by the MOE (2008) as a means to increase the quality of education.

2.3. Teacher Education Institutions

As described in Section 2.2 and illustrated in Figure 2.3, school leavers progressing from Grade 10 have two options depending upon their national exam result. Students with the highest examination results can join the higher education preparatory school system, and study Grades 11 and 12. Students who do not score a high enough score for Grade 11 may have the chance to join either a CTE or TVETC again depending upon examination results at Grade 10 and the number of applicants for a CTE. CTEs are more attractive than TVET because graduates of the 3 year diploma course get teaching positions easily.

There are 32 CTEs in Ethiopia responsible for awarding diplomas to primary school teachers. CTEs are classified under the higher education subsector. They provide classes in regular, evening and summer programs. There are more than 20 different departments or streams in most CTEs. Some of the departments include English, Local language, History, Geography, Chemistry, Biology, Physics, and Mathematics (MOE, 2012b). These departments prepare specialist primary school level teachers in their respective fields.

In most cases, CTE in Ethiopia is regarded as the least attractive higher education level program than universities. Consequently, and similar to most other East African countries, teacher education programs attract students who cannot be admitted to medicine, engineering, and other more attractive options (Ottevanger, van den Akker, & de Feiter, 2007). The coverage of content is similar to that in most eastern African countries. Subject content coverage at both CTEs and universities receives great emphasis. At CTEs, it is the same content as Grades 11 and 12 and moves quickly toward more advanced university level topics with little attention paid to conceptual gaps in the pre-service teachers' understanding of primary school context. In addition, the concept of pedagogical content knowledge is emphasised at CTEs. CTE students have a practice period in primary schools for prospective primary school teachers. Two large CTEs establishments were the sites for this study.

2.4. ICT Policies and their Use in Teaching

2.4.1. ICT policies. The Ethiopian Government has made the development of ICT policy of its strategic priorities consistent with its commitment to the development of ICT as both an industry and an enabler of socio-economic transformation (Dzidonu, 2011). The policy stems from the recognition by the Government, that technology is the key driver and facilitator for

transforming Ethiopia's predominantly subsistence agriculture economy and society into an information and knowledge based economy and society, effectively integrated into the global economy.

Recognising the key role of technology in the socioeconomic development of the country, the Government has taken measures to address major technology challenges, which include poor infrastructure, an inadequately skilled workforce, and high telecommunication costs. It aims to enhance the growth of the ICT industry by, among other things, encouraging investment in the ICT sector with a focus on infrastructure and human resources development (Adam, 2010; Dzidonu, 2011).

In various policy documents, the MOE of Ethiopia describes and emphasises the use of technology to expand students' modes and breadth of learning. For example, under the professional standards for teachers, it is stated teachers must have the knowledge to meet diverse learning needs of students through consistent application of a wide range of effective teaching strategies and the use of technology to foster both independent and collaborative learning (MOE, 2012c). Another policy document called Content and Pedagogical Standards for Mathematics Teachers states that teachers are required to have the skill to integrate current technology as appropriate for instruction (MOE, 2012a). Further, this document demands that mathematics teachers use technology for topic specific applications with statements such as "uses manipulative, Euclidean geometry, coordinate geometry, transformational geometry, and appropriate technology to model mathematical concepts and solve problems." The 1994 Educational policy also affirms the importance of using technology in teaching in all sectors of education in order to promote the quality, relevance, and expansion of education (MOE, 1994).

The government have been implementing a number of programs with the assistance of the United Nations Development Program. It has developed an ICT for Development policy as a framework for the facilitating Ethiopia's ICT led socioeconomic development. Among the objectives of the policy is the promotion of ICT in education at all levels of the education system.

2.4.2. Technology use in teaching. Technologies are being increasingly used in education, even in the most challenging environments in developing countries. The systematic use of technology for learning purposes, however, is still low in developing countries. Students learn basic computer skills and some principles of computer operation, but a lack of equipment limits the practical experience for students and many well trained ICT teachers leave teaching for business and industry jobs (Ottevanger et al., 2007).

Consistent with its policies, the government of Ethiopia has made considerable investment in technology infrastructure, especially at the secondary school and tertiary levels. Currently, 71.6% of secondary schools are equipped with plasma televisions and 26.1% of secondary schools have access to internet services (MOE, 2010).

The government continues the expansion of technology use in education in order to improve the quality of teaching and learning, but for quality improvement to occur, it is necessary to go beyond the provision of more technology infrastructure. Strategies under the Education Sector Development Program cover three main areas aimed at improving the linkage between technology and quality. Firstly, it is the intention to develop and implement a technology responsive technology national curriculum for primary, secondary and higher education as well as for other educational institutions. In secondary schools, plasma television

programs have been prepared in response to ICT national curriculum. The plasma television program is a live, nationally broadcast "plasma" television mode of instruction broadcasted over Internet protocol networks to wide plasma television screens installed in each classroom, via a satellite receiving device named Plasma Display Panels. A second area of challenge is the preparation of teachers to use technology in their teaching. Efforts continue to reinforce the skills of teachers to use technology efficiently. Thirdly, measures have been taken to expand the access of schools to technology infrastructure to allow more students and teachers to benefit from more widely available global information sources. The effort to increase the use technology in teaching is reflected in the national and school levels.

At the national level, the effort to expand the use of technology in education is reflected in the 'technology in education implementation strategy and action plan'. This action plan is a component of wider Ethiopian national education initiatives such as the National SchoolNet initiative aimed at the deployment and exploitation of technology to facilitate the teaching and learning processes within primary, secondary, TVETCs, and CTEs for supporting literacy education and to facilitate the delivery of education (Hare, 2007). Furthermore, teachers are encouraged to use ICT in teaching to facilitate active learning (MOE, 1994; MOE, 2008). Beside this, Ethiopia's national ICT policy has set the stage for growth within the ICT sector including schools. One particular initiative at the national level that has been cited by researchers is the implementation of one laptop per child program. This program is aimed at creating educational opportunities for children by providing each child with a laptop with content and software designed for collaborative, enjoyable and empowering learning (Kocsev, Hansen, Hollow, & Pischetola, 2010). As mentioned in Section 2.3, CTEs are expected to equip teachers with the

skills to use ICT in teaching (MOE, 1994). ICT training is a compulsory course for the primary school teachers. The training approach involves initially teaching basic ICT principles and preliminary practical skills such as switching on and shutting down the computer, word processing, and using Microsoft Encarta (Bass, 2007). The focus of the training is on learning how to use technology tools rather than using technology to enhance learning. In essence, there is a minimal focus on the interconnectedness of technology, pedagogy, and content for effective use of technology in teaching.

At school level, there is an increase in technology access in most urban schools, although no guarantee on using technology for teaching can be derived from the mere presence of ICT in schools (ten Brummelhuis, & Kuiper, 2008). Teachers are encouraged to use technology tools such as computer-based tutorials, drill, and practices programs, simulations, and games, as well as communication tools, and other technology tools to assist classrooms, laboratories, and libraries thereby improving the overall quality of education. Teachers continue to use technology, however, for low level formal academic tasks rather than as a learning tool to support students' active learning (Hare, 2007; Gebremariam, 2004).

Although teachers at all levels are required to integrate technology into their teaching to improve quality of education, there is no clear information or strategy for teachers, however, on how to acquire the knowledge required to do so. In order to address this shortfall, this study documents the design, development and refinement of a job embedded PD program that supported teacher educators to integrate technology in their mathematics teaching as an important step towards helping them to better prepare primary school teachers to use technologies effectively in their own teaching.

2.5. Professional Development

Recognising the importance of PD programs to the quality of education, the Ethiopian MOE included academic and PD programs in its higher education reform plan (World Bank, 2003). Many PD programs for teacher educators at CTEs are, however, associated with the implementation of curriculum reforms or with efforts to improve practice in schools. For example, the Higher Diploma Program (HDP) is designed to prepare teacher educators in line with promoting a student centred teaching approach and the overall professional growth of teachers. The HDP comprises on the job PD program for one academic year targeting teacher educators' competence in learning and teaching methods, assessment methods, and key elements of the roles required of teacher educators' for effective teaching. These include reflection, collaborative work, planning, and coping with change. The successful completion of the one year HDP is becoming a prerequisite for receiving a teaching license without which it will be impossible to join or stay in the teacher education profession in the future as indicated in the Teacher Education System Overhaul handbook (MOE, 2003).

Nevertheless, despite the interest of the government and benefits of stimulating teachers to integrate technology in the teaching and learning process, most CTEs have given little emphasis to such initiatives. Only a few PD programs have focused on technology and these have done so separately from pedagogical and content knowledge. According to Koehler and Mishra (2009) and Mishra and Koehler (2006) at the heart of good teaching with technology are three core components: knowledge of content, of pedagogy, and of technology along with the relationships among and between them.

2.6. Chapter Summary

The primary intention of this chapter was to inform the reader's understanding of the context of Ethiopia and its education system. In summary, the quality of students' performance in mathematics in Ethiopian schools is inadequate at both primary and secondary school levels. The government of Ethiopia continues the expansion of technology use in education in order to improve the poor quality of teaching and learning. In the analysis, it became evident that the government of Ethiopia has set ambitious ICT policies and made a considerable effort to encourage teachers at all levels to use technology in their teaching. There is no clear information or strategy for teachers, however, to acquire the knowledge required to integrate technology in their teaching.

The following chapter, Chapter 3 will examine the theoretical perspectives from the literature in relation to technology integrated teaching in mathematics. The chapter will specifically explore theories on technology use in teaching and knowledge required from teacher educators to use technology effectively in teaching and the characteristics of PD programs in the use of technology in teaching mathematics. The chapter will also provide the theoretical background of the study, particularly the knowledge needed to integrate technology in mathematics teaching by exploring and combining theories. Moreover, the study will explore characteristics of effective PD programs to support teacher educators to integrate technology in their teaching.

Chapter 3 Literature Review

The previous chapter provided an overview of the context of the study. It described the education system in Ethiopia and the quality of mathematics education in that country. It also provided an overview of the teacher education, Information Communication Technology (ICT) policies, technology use in teaching, and Professional Development (PD) program trends for teachers in Ethiopia. This chapter reviews the literature related to the study. It describes gaps in existing knowledge of technology integrated mathematics teaching and explores the characteristics of an effective PD program. The review is organised into seven sections. Section 3.1 examines the impact of technology in teaching mathematics, including its potential to enhance the quality of students' mathematics learning and further improve the quality of education. The second, Section 3.2, explores teachers' efficacy related to content and pedagogical knowledge as a measure of the effectiveness of mathematics teachers. It also examines the technology integration, and the knowledge required to integrate technology in teaching mathematics. Section 3.3 conceptualises the knowledge needed to integrate technology in teaching mathematics taking into account Section 3.1. Section 3.4 illustrates some of the barriers to the integration of technology in teaching and the importance of teachers' knowledge of technology, pedagogy and content to technology integrated teaching. Section 3.5 describes the characteristics of an effective PD program focused on the integration of technology in teaching mathematics. Theories relevant to the study are synthesised in Section 3.6. The final section, Section 3.7 provides a summary of the chapter.

3.1. Technology in Teaching Mathematics

Studies have shown that the use of ICT as a learning tool, within meaningful learning contexts can lead to significant positive educational and pedagogical outcomes in the schools and bring major benefits to both learners and teachers (e.g., Ayub, Mokhtar, Luan, & Tarmizi, 2010; Su, 2008; ten Brummelhuis & Kuiper, 2008; Voogt, 2008). These findings have motivated university, college and school teachers to integrate technology into teaching to achieve better learning outcomes. ICT can support constructivist pedagogy, as students use technology to explore and reach an understanding of concepts (e.g., Bu & Haciomeroglu, 2010; Chee, Horani, & Daniel, 2005; ten Brummelhuis & Kuiper, 2008). Particularly, for teaching mathematics, there are multiple ICTs, which can enhance teachers' instruction and students' active engagement and learning opportunities. Chee et al. (2005) stated that ICT based learning environments in mathematics provide opportunities for active learning that can enable students to perform at higher cognitive levels, support constructive learning, and promote scientific inquiry and conceptual change. For such purposes, a wide range of virtual educational environments and applications are available for mathematics education (e.g. simulations and modelling tools, microcomputer based laboratories, GeoGebra, Computer Algebra System, web resources and environments, spreadsheets and databases, etc.). Such tools offer a variety of possibilities for both students and teachers. For instance, by using simulations, students may vary a selection of input parameters, observe the extent to which each individual parameter affects the system under study, and interpret the output results through an active process of hypothesis making, and testing ideas. Alternatively, they can explore combinations of factors and observe their effects on the evolution of the system under study (Chee et al., 2005).

Familiar applications such as spreadsheet applications that have been available since the early 1980s can have powerful uses. They are electronic tables in which one can enter a formula that efficiently performs calculations on a number or a series of numbers. Spreadsheets can enable students to ask and answer "What if . . . ?" questions with many numbers rather than a single value (Julie & Douglas, 1998). Clayton and Sankar (2009) found serendipitously that using spreadsheets to teach statistics influenced students' attitudes toward the subject. Their use to teach statistics can allow students to develop transferable spreadsheet skills while also building their confidence in such skills as data entry and manipulation, writing formulae, using absolute and relative cell references, using array formulae, and accessing to build in functions (Michael & Van Auken, 1998). Furthermore, spreadsheets can serve as functional machines for exploring what happens when a variable changes. As students experiment with different input values in a spreadsheet, they can see relationships unfold visually and efficiently. Such flexible software can encourage students to try out possibilities and discover patterns in their results (Clayton & Sankar, 2009; Michael & Van Auken, 1998). There are also mathematics specific software packages such as dynamic geometry software and graphic packages, which can facilitate mathematics teaching (Johnston-Wilder & Johnston-Wilder, 2004).

In summary, there are multiple technologies (including software and programs) that can facilitate students' learning. Hence, there is potential to use these technologies to enhance the quality of students' mathematics learning and further improve the quality of education. Increased availability of ICT resources, however, does not guarantee increased rates of effective integration of technology (Etmer, 2005; Hew & Brush, 2007); rather the integration of ICT tools into

teaching demands specific skills of teachers that can be enhanced through different PD programs (Peeraer & Van Petegem, 2010).

3.2. Knowledge for Effective Mathematics Teaching

The effectiveness of teachers is influenced by their initial teacher education in preparing them for their future careers (Hsieh et al., 2011; van Dijk & Kattmann, 2007). The content, pedagogy and approaches taught in courses taken by future teachers should be consistent with the needs of teaching in schools (Hsieh et al., 2011; van Dijk & Kattmann, 2007). There is consensus that teachers need to be competent in pedagogy and content in order to be effective teachers (e.g., Ball, Thames, & Phelps, 2008; Hill, Schilling, & Ball, 2004; Loughran, Mulhall, & Berry, 2008). In recent years, technology integration into teaching has been recognised as a further requirement fostering students' learning. Studies have reported that ICT has the potential to enhance teaching and learning through enriching the curriculum, improving delivery, extending methods of presenting information, offering new opportunities through technological techniques, and allowing teachers to manage and reduce their administrative workloads (e.g., Fuglestad, 2009; Ingram, 2007). Integrating technology in new student centred learning approaches in teaching requires conceptualising teachers' knowledge in organised ways. These types of knowledge required for teaching are discussed in the following two sections.

3.2.1. Pedagogical and subject content knowledge in mathematics. Studies have showed that the professional competence of teachers included substantive knowledge regarding formal content, particular pedagogy (e.g., mathematics pedagogy) and general pedagogy (e.g., Blömeke, Suhl, & Kaiser, 2011; Schmidt et al., 2008). Discussion of the interplay of different components of knowledge to enhance teaching competencies started as far back as

1980s. One of the pioneers of work on knowledge for teachers was Shulman (1986) who introduced the term Pedagogical Content Knowledge (PCK) as a basic requirement for teachers. According to Shulman (1987, p. 8) PCK represents “the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organised, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction”. Subsequently, Shulman’s idea of PCK has been applied in different subject areas. For example, Phelps and Schilling (2004) used PCK in language teaching to develop survey measures of the content knowledge of teachers needed to teach elementary reading. In physics teaching, Halim and Meerah (2002) used PCK to explain teachers' pedagogical content knowledge (PCK) of selected physics concepts with its generic characteristics.

In relation to mathematics, researchers such as Ball and colleagues (e.g., Ball, Thames, & Phelps, 2008) and Park and colleagues (e.g., Park et al., 2011; Park & Oliver, 2008) have established PCK as essential to the effectiveness of mathematics teachers. Some, such as Ball et al. (2008) have, however, argued that referring to PCK in mathematics teaching in its generic form can be seen as limiting the importance of understanding mathematics subject matter in teaching and teachers’ knowledge about the subject that is required by effective mathematics teachers. They further argued the distinction of PCK in specific subjects of study can make an important contribution to understanding the qualities and resources needed for effective teaching (Ball & Forzani, 2009; Ball et al., 2008; Hill et al., 2004). Mathematics teacher educators have developed a variety of conceptualisations of the knowledge needed to teach mathematics.

Rowland and Fay (2007) identified four different categories of knowledge required for teaching mathematics: foundation, transformation, connection and contingency. Their knowledge

quartet was derived from constant comparison across 24 videotaped lessons of elementary pre-service teachers towards the end of their initial teacher education. The knowledge quartet comprised four broad dimensions, through which the mathematics related knowledge of these teachers could be observed in practice. These dimensions and their definitions (Rowland, Turner, Thwaites & Huckstep, 2009) are summarised in Table 3.1.

Table 3. 1

The Knowledge Quartet (Rowland et al., 2009, p. 29)

Knowledge categories	Description
Foundation	Adherence to textbook, Awareness of purpose, Concentration on procedures, Identifying errors, Overt subject knowledge, Theoretical underpinning, Use of terminology
Transformation	Choice of examples, Choice of representation, Demonstration
Connection	Anticipation of complexity, Decisions about sequencing, Making connections between procedures, Making connections between concepts, Recognition of conceptual appropriateness
Contingency	Deviation from agenda, Responding to children's ideas, Use of opportunities

The knowledge quartet framework has been used as a framework for lesson observation, and reflection to identify and develop teachers' mathematics content knowledge for teaching. The practical application of the knowledge quartet framework, however, depends on teachers and teacher educators understanding the broad characteristics of each of the four dimensions. When this is the case, the knowledge quartet framework provides a shared language for discussion and reflection on mathematics teaching (Rowland & Fay, 2007).

Chick, Baker, Pham, and Cheng (2006) developed a PCK framework considering facets of knowledge contributing to teachers' decision making. The categories they identified were Clearly PCK - those aspects of teaching which are most clearly a blend of content and pedagogy; Content Knowledge in a pedagogical context which describes those aspects of knowledge drawn most directly from content; and Pedagogical Knowledge in a content context comprising knowledge which has been drawn most directly from pedagogy. In each category, they identified finer categories with examples of teacher practice that evidenced the use of specific knowledge types. For example, the pedagogical knowledge in a content context category includes setting goals for learning specific or general mathematics, getting and maintaining students' focus and classroom techniques for describing classroom practices. They indicated that these characteristics are evident, for example, when a teacher is able to describe a goal for students' learning directly related to specific or general mathematics content, discuss strategies for engaging students and discuss generic classroom practices respectively.

Ball and colleagues proposed a distinction between knowledge of mathematics and knowledge about mathematics (Ball et al., 2008) and posited that mathematics teachers require both. Knowledge of mathematics is knowledge of concepts, ideas, and procedures and how they work, whereas knowledge about mathematics concerns how one decides that a claim is true, a solution complete, or a representation accurate. These classifications are based on the assumption that the improvement of mathematics teaching demands, among other things, understanding of its mathematical nature and requirements, and the provision of opportunities for teachers to acquire the appropriate mathematical knowledge and skill to teach mathematics well (Thames & Ball, 2010).

Ball et al. (2008) developed a model to show the correspondence between their map of the domain of content knowledge for teaching mathematics and two of Shulman's (1986) initial categories: subject matter knowledge and pedagogical content knowledge as shown in Figure 3.1. Ball et al. (2008) suggested that Shulman's Content Knowledge comprises three kinds of knowledge Common Content Knowledge (CCK), Specialised Content Knowledge (SCK), and Horizon Content Knowledge (HCK) and that Pedagogical Content Knowledge comprises Knowledge of Content and Students (KCS); Knowledge of Content and Teaching (KCT) and Knowledge of Content and Curriculum (KCC).

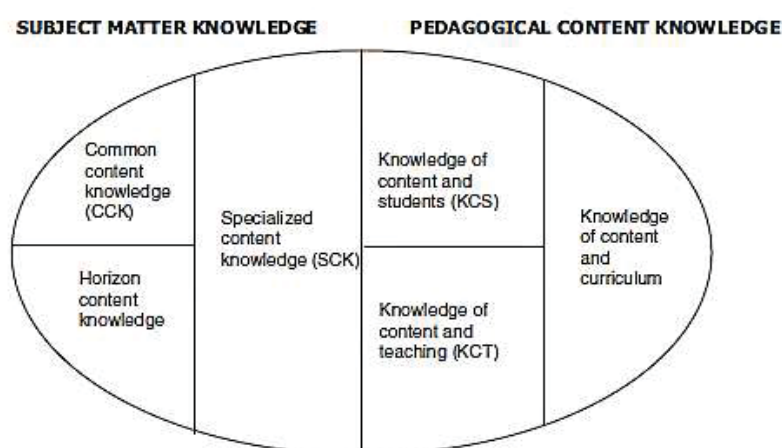


Figure 3.1. Domains of mathematical knowledge for teaching (Ball et al., 2008, p. 403).

An illustration of what these categories look like in practice will now be discussed in relation to the following scenario shown in Figure 3.2.

Using the scenario as a starting point the following can be inferred about the teacher's knowledge of teaching mathematics in relation to Ball et al's. (2008) framework. Firstly, the teacher knew the answer for such equations generally and was able to solve the problem. He was unable to explain the mathematics that he knew even though knowledge and skill in teaching

context demanded an explanation. The knowledge the teacher demonstrated in Ball et al.'s terms is CCK.

Scenario: A teacher asked students to answer the following question in grade 8 mathematics.

$$\frac{10}{0} = 10,000,000 = \underline{\hspace{2cm}}$$

A student answered '10,000,000', but the teacher claimed that the answer is undefined because a number can't be divided by zero and it is undefined. The student started to challenge the teacher by picking examples from the teacher's previous explanations. The student's argument was the following:

One day the teacher was explaining about approximation of decimal numbers and stated that:

$$0.00000001 \approx 0$$

Hence, the student calculated as follows:

$$\text{As } 0.00000001 \approx 0, \quad \frac{10}{0} = \frac{10}{0.00000001} = 10 \times 10^8 = 10,000,000$$

The teacher had no means of explaining his argument other than saying it is undefined.

Figure 3.2. Scenario to illustrate Ball et al. (2008) knowledge categories.

Secondly, although the teacher was teaching the concept of approximating decimal numbers, he was not aware of different interpretations of the approximate numbers and division by zero that students need to distinguish explicitly. In this regard, teaching requires knowledge beyond that being taught to students. For instance, it requires understanding different interpretations of the approximations and the meaning of division by zero that students need to understand. It involves the use of mathematical knowledge that might be taught directly to students so that they can develop an understanding. People who are not mathematics teachers do not require this knowledge. Ball et al. (2008) called it SCK.

Thirdly, in teaching approximation a teacher needs to anticipate what students are likely to think and what they will find confusing. The knowledge the teacher required includes knowing

about students and their mathematical thinking, and development in the context of learning mathematics. This knowledge is called KCS (Ball et al., 2008; Hill et al., 2005).

Fourth, the teacher showed no evidence of being able to evaluate the instructional advantages and disadvantages of representations used to teach approximation and division by zero through identifying what different methods and procedures afford teaching. This demands knowing about teaching and knowing about mathematics. According to Ball et al. (2008), the knowledge teachers require to design instructional approaches for particular mathematics content is called KCT.

Close study of teachers' knowledge specific to particular mathematics content is helpful for the following reasons. Firstly, it can help in studying the relationships between teachers' content knowledge and their students' achievement. For example, it would be useful to ascertain whether there are aspects of teachers' content knowledge that predict student achievement, more than others do (e.g., SCK). This could direct and help teacher education systems to provide appropriate PD for teachers (Capraro, Capraro, Parker, Kulm, & Raulerson, 2005). Secondly, it could be useful to study whether and how different approaches to teacher development have different effects on particular aspects of teachers' pedagogical content knowledge (Abell, Rogers, Hanuscin, Lee, & Gagnon, 2009) administered in the particular field of study (e.g. Mathematics). Thirdly, the categories of content knowledge for teaching might inform the design of support materials for teachers and teacher education and clarify what is required in a curriculum for the content preparation of teachers and teachers' professional development tied to professional practice and to the knowledge and skill demanded by the work (Ball et al., 2008).

The teacher knowledge frameworks discussed show teachers' knowledge of mathematics alone is insufficient to support their attempts to teach the subject for understanding. An important distinction is that made by Ball and colleagues (Ball et al., 2008) between general mathematical knowledge and mathematical knowledge that is specifically useful in teaching mathematics. It is important that the identification of elements of the knowledge required by teachers can lead to action in order to promote student understanding and prepare future mathematics teachers more efficiently. Furthermore, Ball et al. emphasised that the mathematical knowledge needed for teaching mathematics is different from the mathematical knowledge typically taught in university mathematics classes.

The knowledge required for teaching school mathematics has implications for teacher education colleges and teacher educators. Understanding PCK in particular has been recognised as helpful for mathematics educators in devising PD programs for teachers (Ball et al., 2008). According to a number of studies (e.g., Ball & Forzani, 2009; Hill et al., 2005; Hill et al., 2004), mathematics teachers' PD programs can be guided by understanding future teachers' PCK. A clear and explicit understanding of the categories of knowledge for teaching can inform the design of support materials for teachers, preparation of teachers, and design of PD program (Ball et al., 2008; Grossman et al., 2009). This means that teacher educators should draw attention to the connection between knowledge of mathematics and knowledge of mathematics teaching. There is consensus that teachers of mathematics need to be educated about both from "mathematics knowledge" and "pedagogical content knowledge" aspects (Krauss, Baumert, & Blum, 2008; Turnuklu & Yesildere, 2007). This knowledge has to be reflected in the teaching of teacher educators so that future mathematics teachers can learn from and apply their learning in

their own future teaching at primary or secondary school levels (Loughran & Berry, 2005). In this study it is assumed that the quality of pre-service teachers is dependent upon the quality of teacher educators in parallel to the comments provided by Loughran and Berry (2005). They suggested that creating opportunities for learning by teacher educators about teaching with pre-service teachers is meaningful and facilitated pre-service teachers' professional development and growth. Teacher educators' understanding of the knowledge required by teachers of mathematics has therefore, practical implications for the quality of pre-service teachers and hence future teachers of mathematics.

3.2.2. Technology knowledge in teaching. Most educationalists have seen ICT as both a means and a catalyst to innovate education (e.g., Fidalgo-Neto et al., 2009; Hellsten, 2006). Integrating ICT in teaching, however, is challenging for most teachers. Success in integrating ICT in mathematics lessons is not only dependent upon knowledge of the existing software that is used by mathematics teachers but also on sound pedagogical knowledge of how to integrate its use in teaching (Chee et al., 2005).

Various studies (e.g., Drent & Meelissen, 2008b; Pelgrum & Voogt, 2009) have been conducted on the knowledge requirements of teachers to use ICT in teaching. Most of them emphasise three aspects. These are: ICT technical knowledge, ICT supported pedagogical knowledge, and ICT supported subject content knowledge. Table 3.2 shows some of the studies that have argued for various basic requirements in integrating ICT in teaching. The studies shown in Table 3.2 were selected based on the emphasis they provided on the knowledge needed to integrate ICT in teaching and covered a range of skills particularly in science and mathematics.

For instance, Drent and Meelissen (2008) indicated that ICT should not just be regarded as a tool, which can be added to or used as a replacement of existing teaching methods, rather, teachers and students should have the knowledge to use ICT as an important instrument to support new ways of teaching and learning. Liu (2011) emphasised teacher's pedagogical skill is important for proper integration of technology teaching. Teachers should have sound pedagogical skills to realise the potential advantage of ICT in helping students to learn more effectively.

Table 3. 2

Knowledge Requirements to Use Technology in Teaching

Skills	Studies							
	Drent and Meelissen (2008)	Pelgrum and Voogt (2009)	UNESCO (2008)	Liu (2011)	Kalogiannakis (2010)	Mishra and Koehler (2006)	Stein, Ginns, and McDonald (2007)	
Basic ICT technical knowledge/Skill	✓	✓	✓	✓		✓	✓	
ICT supported pedagogical knowledge		✓	✓	✓	✓	✓	✓	
ICT supported content knowledge		✓	✓			✓		
Knowledge/skills for ICT integration		✓	✓			✓		

UNESCO (2008) created ICT competency standards for teachers with six components: policy, curriculum and assessment, pedagogy, ICT, organisation, and teacher training. They also identified three approaches for using technology in teaching (technology literacy, knowledge deepening, and knowledge creation). For instance, the technology literacy approach includes basic digital literacy skills along with the ability to select and use appropriate technologies.

In addition, many studies have advocated the importance of technological, pedagogical, and content knowledge for successful use of technology for effective teaching (e.g., Harris, Mishra, & Koehler, 2009; Mishra & Koehler, 2006; Niess, 2005; Polly, 2011). In this regard, Loughran and Berry (2005) indicated that teacher educators need to be competent in terms of technology, pedagogy, and content knowledge in order to model this knowledge for their students in their teaching. In addition, teacher educators' should be supported through PD to acquire such knowledge so that they can effectively integrate ICT in their teaching (e.g., Harris, Mishra, & Koehler, 2009; Mishra & Koehler, 2006; Niess, 2005). As a result, most ICT teachers' PD program initiatives are advised to focus on pedagogical, content and technological aspects (Chee et al., 2005; Jimoyiannis, 2010) and their interplay (Mishra & Koehler, 2006).

The importance of content, pedagogy and technology knowledge to integrate technology in teaching is an extension of the idea of PCK by Shulman (1986) resulting in the "Technological Pedagogical Content Knowledge" (TPACK) framework (Mishra & Koehler, 2006). The following section provides a description of the TPACK framework.

3.2.2.1. *Technological Pedagogical Content Knowledge*. As discussed in Section 3.2.1, the idea of integrated knowledge for teachers started with Shulman's (1986) notion of PCK, which focused on the importance of treating the amalgam of pedagogical and content knowledge as a distinct knowledge type that could be considered a basic requirement for effective teaching. Shulman (1986) argued that when pedagogy is ignored and attention is paid only to the content, effective teaching is impossible as pedagogy is held accountable for the transfer of subject content. The idea of PCK has been used as a basis for considering the knowledge needed by teachers to facilitate learning. However, ICT has become increasingly

prominent in students' learning and lives (ten Brummelhuis & Kuiper, 2008) which led to the addition of technology component to the PCK framework (Niess, 2005).

Following the introduction of the TPACK framework, studies indicated that while teaching with technology a teacher should consider the interplay of technology, pedagogy and content in a particular context (e.g., Koehler & Mishra, 2009; Mishra & Koehler, 2006; Niess, 2005).

According to Koehler and Mishra (2009), context shown in Figure 3.3 includes students' prior knowledge and classroom situations.

Koehler and Mishra (2009) advocated that meaningful teaching with technology occurs when technology, pedagogy and content knowledge are connected in a classroom practice and when teachers are involved in PD program practices.

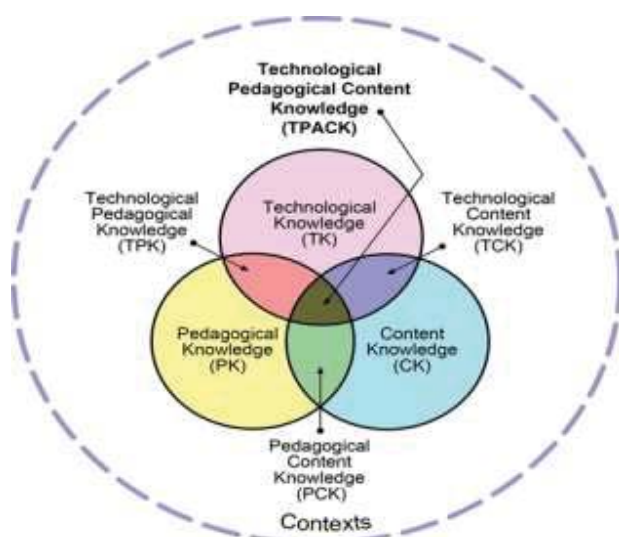


Figure 3. 3. Technological Pedagogical Content Knowledge framework (Reproduced by permission of the publisher, © 2012 by tpack.org).

The combination of the three components of knowledge (technological, pedagogical and content) should reinforce each other to realise the advantages of technology in the teaching and learning process. The interplay of the three components (technological, pedagogical and content

knowledge) results in a range of different combinations (Koehler & Mishra, 2009). These are presented in Table 3.3 along with a brief explanation of each category.

Table 3. 3

Description of TPACK Framework

Component	Description
Technological Knowledge (TK)	Includes skills of teachers to properly use a particular technology. This could be using a particular software program and installing or removing it
Pedagogical Knowledge (PK)	Knowledge about process and practices of teaching. This knowledge, for example, includes students' learning styles, classroom management, students' evaluations and lesson planning.
Content Knowledge (CK)	Knowledge of a subject matter to be taught. This knowledge demands understanding core principles, facts, theories, procedures and concepts of a particular subject matter.
Pedagogical Content Knowledge (PCK)	Knowledge of how particular pedagogical approaches are suited to teaching particular content and vice versa.
Technological Content Knowledge (TCK)	Knowledge of how technology and content interact in effective teaching. It includes teachers' understanding of how the subject matter can be changed by the use of technology.
Technological Pedagogical Knowledge (TPK)	Knowledge of how the use of various technologies with different pedagogical approaches. It involves recognising and making use of the affordances of technologies and choosing pedagogical approaches that fit particular technologies and vice versa.
Technological Pedagogical and Content Knowledge (TPACK)	Knowledge that is more than the sum of its three components (content, pedagogy, and technology). It is the knowledge of the basis for effective teaching with the application of technology and requires an understanding of pedagogical techniques that use technologies in constructive ways to assist students to overcome difficulties and to learn content effectively

According to Koehler, Mishra and Yahya (2007) good teaching with technology requires understanding the mutually reinforcing relationships between all three elements taken together to develop appropriate and context specific approaches. The TPACK framework can, therefore, be used to determine the pedagogy required to teach specific content using technologies effectively (Jimoyiannis, 2010). Moreover, the TPACK framework could be used to diagnose teachers' difficulties with integration of technology in teaching and identify areas in target for PD for successful integration (Koehler & Mishra, 2009; Niess et al., 2009; Niess, van Zee, & Gillow-Wiles, 2011).

The TPACK framework and the underpinning assumption that teaching with technology requires a special kind of knowledge is of worth, but it is a generic framework. Specifying the nature of the content and pedagogical knowledge needed to integrate technology in teaching for a particular subject has the important advantage of allowing the TPACK framework to be used with greater precision. The following section describes how the mathematical knowledge for teaching of Ball and colleagues, and Mishra and Koehler's (2006) TPACK framework can be combined to produce a new framework for technology integrated mathematics teaching. The resulting framework underpinned the current study.

3.3. Conceptualising Technology Integrated Mathematics Teaching

Adapting the TPACK framework to apply specifically to mathematics teaching requires understanding the three components (technology, pedagogy and content) from the perspective of mathematics teaching. The advantage of using Ball et al. (2008) rather than other conceptualisations of mathematics teacher knowledge stems from its grounding in Shulman's notion of PCK which also informed the TPACK framework. Specifically, Ball et al. (2008)

elaborated Shulman's PCK in relation to mathematics and considered the role of specialised mathematics content knowledge in teaching, whereas, Mishra and Koehler (2006) extended Shulman's PCK to include technology. The focus of this section is to combine the TPACK framework and Ball et al.'s (2008) Mathematical Knowledge for Teaching (MKT).

Although the TPACK framework starts from the definition of PCK of Shulman (1987), this new development begins from the more detailed conceptualisation of MKT (Ball et al., 2008). In both cases, technological knowledge (TK) is seen as a component to be added. This is illustrated in Figure 3.4 with the left side of the figure showing the addition of TK to Shulman's notion of PCK and the right side showing its addition to Ball et al.'s (2008) MKT framework.

The resulting TPACK framework (shown in Figure 3.5) is reconceptualised as the Specialised Technological and Mathematics Pedagogical Knowledge (STAMPK) framework for teaching mathematics with the application of technology as shown in Figure 3.5. The word 'specialised' is added in each construct of the STAMPK framework except TK to indicate that the concept is mainly derived from Ball's et al. idea of specialised mathematical knowledge and referring to specialist mathematics teaching.

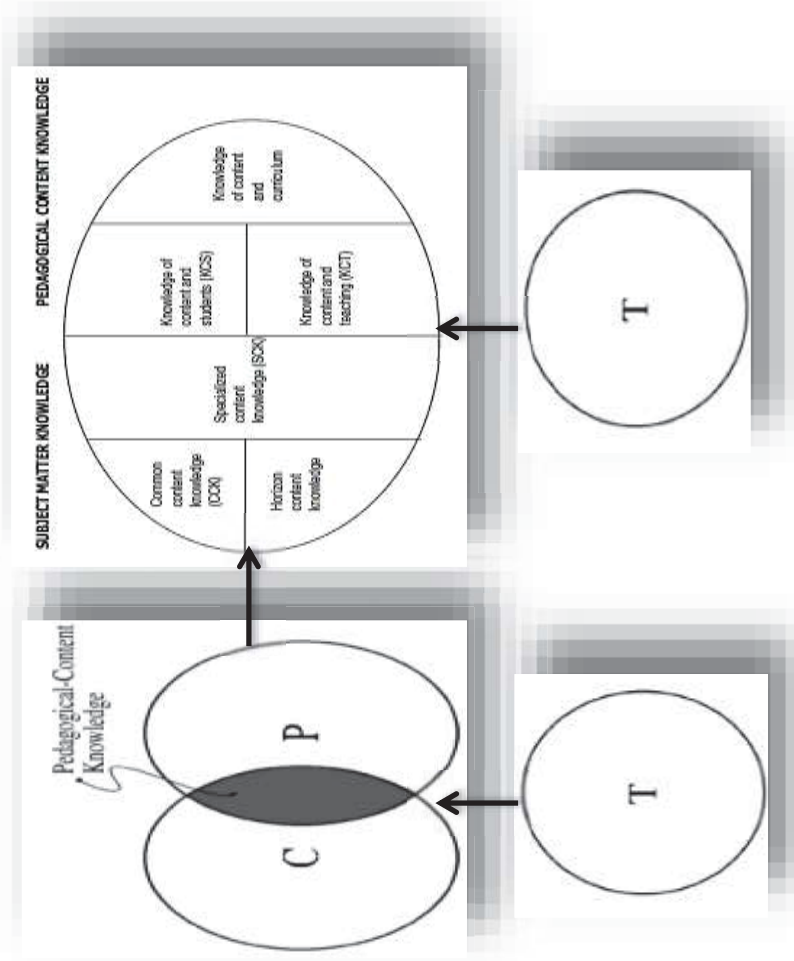
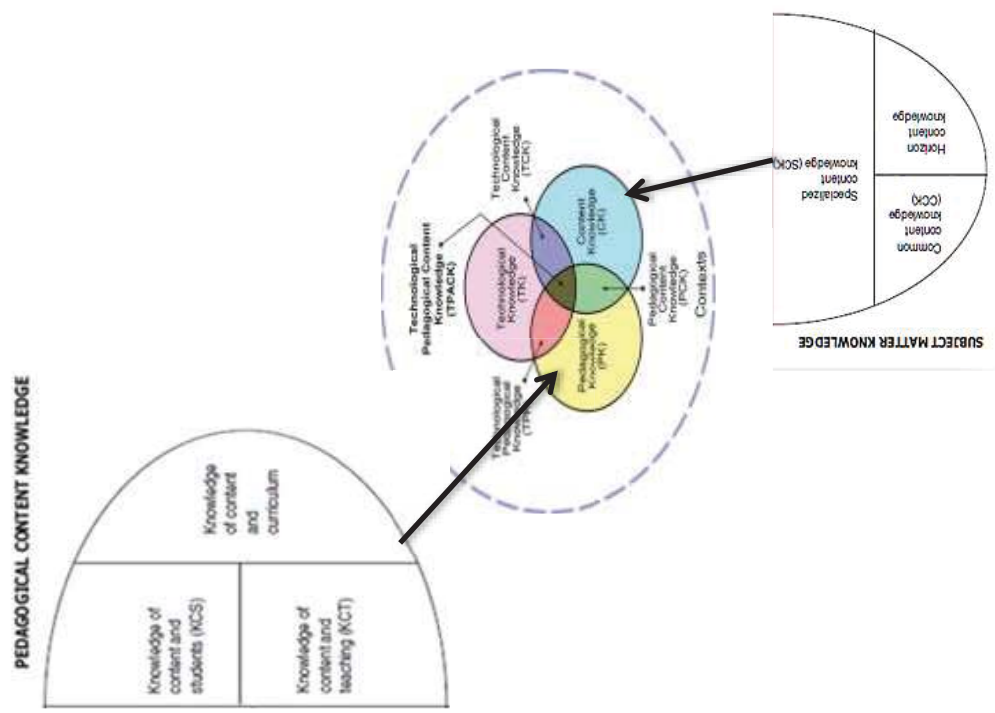


Figure 3. 4. Explaining TPACK in terms of mathematics teaching.

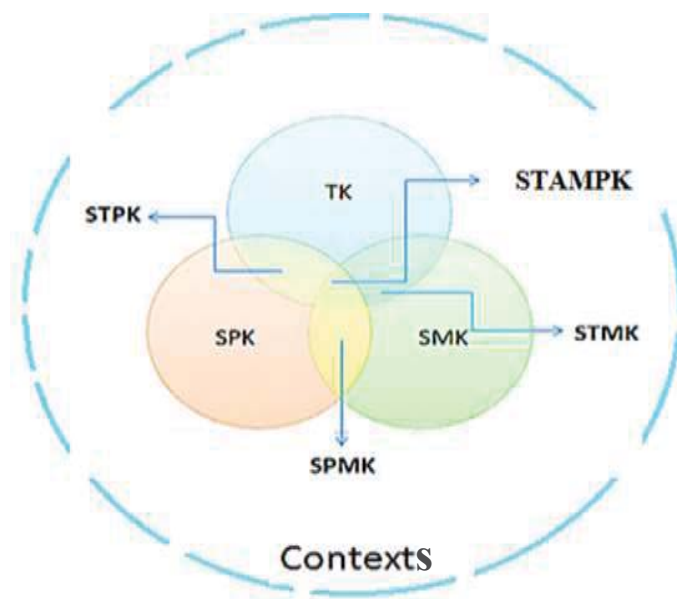


Figure 3. 5. The knowledge required in teaching mathematics with technology (Getenet & Beswick, 2013).

In the STAMPK framework, Mishra and Koehler's (2006) Content Knowledge (CK) is redefined as Specialised Mathematics Knowledge (SMK); Pedagogical Knowledge (PK) as Specialised Pedagogical Knowledge (SPK); Pedagogical Content Knowledge (PCK) as Specialised Pedagogical Mathematics Knowledge (SPMK); Technological Content Knowledge (TCK) as Specialised Technological Mathematics Knowledge (STMK); Technological Pedagogical Knowledge (TPK) as Specialised Technological Pedagogical Knowledge (STPK); Technological Pedagogical Content Knowledge (TPACK) as Specialised Technological and Mathematical Pedagogical Mathematics Knowledge (STAMPK). Technological Knowledge (TK) remains as defined by Mishra and Koehler's (2006). In the following sections, the STAMPK framework is explained, particularly in terms of how it is distinct from the corresponding components of the TPACK framework.

3.3.1. Specialised Mathematics Knowledge. Content knowledge as used in the TPACK framework is redefined in terms of Ball et al.'s (2008) Specialised Mathematics Knowledge (SMK) to emphasise the mathematical focus of content knowledge in the reconceptualisation of the TPACK framework for mathematics teaching. This knowledge is distinct from Mishra and Koehler's (2006) generic content knowledge and is not simply mathematics content knowledge. Rather, it is specialised mathematics knowledge (SMK) that is needed by teachers of mathematics but not the general population or teachers of other subjects in addition to the Common Mathematical Knowledge (CCK). As explained by Ball et al. (2008) such knowledge includes unique mathematical understanding and reasoning that is more than knowing the subject matter.

3.3.2. Specialised Pedagogical Knowledge. Ball et al. (2008) did not define pedagogical knowledge, but described PCK for mathematics teaching in terms of knowledge of content and students, content and teaching, and content and curriculum (see Figure 3.1). Nevertheless, there are parallels with the pedagogical knowledge used by Mishra and Koehler (2006). Mishra and Koehler defined pedagogical knowledge as:

deep knowledge about the processes and practices or methods of teaching and learning and how it encompasses, among other things, overall educational purposes, values, and aims. This is a generic form of knowledge that is involved in all issues of student learning, classroom management, lesson plan development and implementation, and student evaluation. It includes knowledge about techniques or methods to be used in the classroom; the nature of the target audience; and strategies for evaluating student understanding. It is about how students construct

knowledge, acquire skills, develop habits of mind and positive dispositions toward learning. (p. 1026)

From this definition one can see the importance of teaching methods (analogous to Ball and colleagues' Knowledge of Content and Teaching), knowledge of students (analogous to Ball and colleagues' Knowledge of Content and Students), and knowledge of the curriculum (analogous to Ball and colleagues' knowledge of Content and Curriculum) which are pertinent to mathematics teaching. With these understandings, the definition can be reconceptualised for mathematics teaching, with its reliance on specialised mathematics knowledge, as Specialised Pedagogical Knowledge (SPK).

3.3.3. Specialised Pedagogical Mathematics Knowledge. The intersection of SPK and SMK represent the concept of Specialised Pedagogical Mathematical Knowledge (SPMK) and take the place of PCK in Mishra and Koehler's (2006) TPACK framework. Having defined Specialised Mathematics Knowledge (SMK) and Specialised Pedagogical Knowledge (SPK), SPMK can be understood as related to the mathematics specific and specialised (as opposed to generic or everyday) knowledge for teaching mathematics. It includes knowledge of the way in which mathematical concepts can be represented, the affordances of particular mathematical problems, and the specific difficulties that students are likely to encounter in relation to particular mathematical concepts.

3.3.4. Specialised Technological Mathematics Knowledge. The intersection of Technological Knowledge and SMK results in Specialised Technological Mathematics Knowledge. This is knowledge of teachers of mathematics in which the application of technology influences mathematics content. Teachers' selection of technology should fit with the

special type of mathematics knowledge. For example, the use of spreadsheets could transform the task of explaining the difference between a square and a rectangle to one of creating, changing and checking the properties of many figures that fit the definition of a rectangle and identifying that some of these are square. Specialised Technological Mathematical Knowledge allows teachers to identify and use technology appropriately to facilitate the teaching of specific mathematics concepts effectively.

3.3.5. Specialised Technological Pedagogical Knowledge. The intersection of TK and SPK (with the definition given above) gives rise to Specialised Technological Pedagogical Knowledge (STPK). This is the knowledge required by mathematics teachers in which teachers' mathematics specific pedagogical knowledge is integrated with the application of technology.

3.3.6. Specialised Technological and Mathematics Pedagogical Knowledge. Finally, the interplay of TK, SMK, and SPK gives rise to Specialised Technological and Mathematical Pedagogical Knowledge (STAMPK). This is the unique knowledge for teaching mathematics with the application of technology. This knowledge is different from a simple addition of these three knowledge types. Rather, the integration of these three knowledge types enables teachers to incorporate technology into mathematics specific pedagogies effectively, drawing on specialised knowledge of mathematics in such a way that students are assisted to make meaning of the targeted mathematical ideas.

Hence, teaching mathematics successfully with technology requires each component of knowledge described in the STAMPK framework as well as the knowledge types arising from their constructive combination as was the case with TPACK. Their application will depend upon the particular context in which they are employed with such things as the availability of

technologies, time, the nature of students, and course assessments. The contextual and specific nature of STAMPK provides definitions of each component of the STAMPK framework.

The concepts can be exemplified. Suppose a teacher uses the mathematical software called GeoGebra to teach the area of a rectangle. The teacher begins by asking students to determine the number of square units needed to cover this rectangular region shown in the GeoGebra screen shot provided in Figure 3.6.

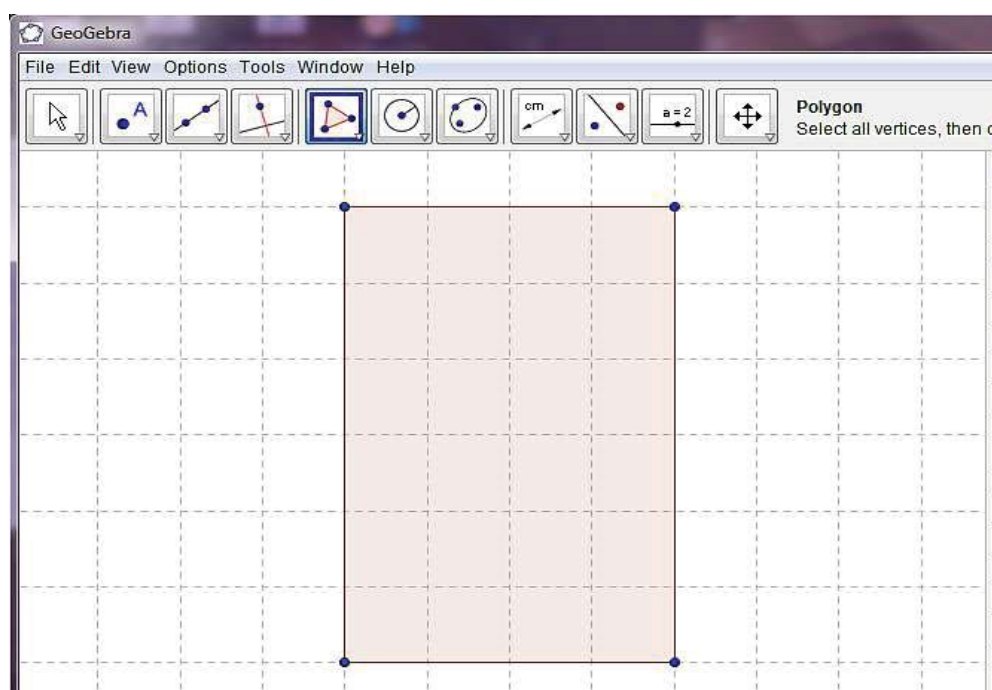


Figure 3. 6. Screen shot from GeoGebra.

Table 3.4 defines the concept SPK, SMK, TK, SMPK, STMK, STPK, and STMAPK with the context of teaching area of a rectangle using dynamic geometry software such as GeoGebra.

Table 3. 4

Examples of SPK, SMK, TK, SMPK, STMK, STPK, and STMAPK

Components	Examples in this context	
Specialised Mathematics Knowledge (SMK)	Knowing	<ul style="list-style-type: none"> • how to calculate the area of a rectangle • the formula for calculating rectangular area • the relationship between the formula and number of squares • the appropriate units for area measurement • that squares are a particular kind of rectangle • the relationship between changing the side lengths of a rectangle and the resultant change in area
Specialised Pedagogical Knowledge (SPK)	Knowing	<ul style="list-style-type: none"> • that students may know the formula, but not have a concept of area as a covering of a surface • how to teach the area of a rectangle by using the formal formula teacher appreciates the importance of highlighting the inclusion of squares in the category of rectangles – something many students find difficult to appreciate • The design and management of effective group work and other pedagogies
Technological Knowledge (TK)	Knowing	<ul style="list-style-type: none"> • how to operate GeoGebra and its functionalities, e.g., how to construct a rectangle and find the area • how to construct a rectangle on a square grid as shown in Figure 3.6 • how to manipulate the figure on the grid
Specialised Pedagogical Mathematics Knowledge (SPMK)	Knowing	<ul style="list-style-type: none"> • to include both square and non-square examples of rectangles • to provide examples of squares and non-squares not aligned with the grid • to make explicit the connection between area as the number of squares and the use of square units for area measures
Specialised Technological Mathematics Knowledge (STMK)	Knowing	<ul style="list-style-type: none"> • how to use GeoGebra to translate and rotate a square of fixed area on a grid could be a useful way to illustrate the conservation of area in terms of the constant total number of unit squares enclosed
Specialised Technological Pedagogical Knowledge (STPK)	Knowing	<ul style="list-style-type: none"> • strategies for using GeoGebra in small groups and with a whole class • strategies for familiarising students with the software
Specialised Technological and Mathematical Pedagogical Knowledge (STAMPK)	Knowing	<ul style="list-style-type: none"> • the affordances of GeoGebra in relation to teaching rectangle area • how teaching the area of a rectangle might change as a result of the availability of GeoGebra • how to maintain the focus on the mathematics rather than the technology

Based on the reasoning outlined and illustrated above, the TPACK framework was reconceptualised for the specific subject of mathematics using the three new components for teaching mathematics and defined in Table 3.5.

Table 3. 5

The Knowledge Required in Teaching Mathematics Using Technology (STAMPK)

Component	Description
Specialised Mathematics Knowledge (SMK)	The knowledge about actual mathematics concepts that are to be learned or taught and specialised mathematics knowledge for teaching. This implies that teachers must know and understand the subject that they teach and the mathematical knowledge and skill unique to teaching. For example, rather than simply knowing how to perform fraction calculations, teachers need to understand the multiple and subtly different meanings of fractions (e.g., as a division, as parts of a whole, as points on a number line).
Specialised Pedagogical Knowledge (SPK)	The knowledge required to understand the nature of the target students as learners of particular mathematical ideas. This helps teachers to anticipate what students are likely to think and what they will find confusing and ways that the development of their understanding can be facilitated. This knowledge requires of teachers the ability to hear and interpret students' emerging and incomplete thinking. Each of these tasks requires an interaction between specific mathematical understanding and familiarity with students and their mathematical thinking.
Technological Knowledge (TK)	Technology knowledge refers to the knowledge about various technologies, ranging from low-tech technologies to digital technologies such as the Internet, digital video, interactive whiteboards, and software programs (Mishra & Koehler, 2006).
Specialised Pedagogical Mathematics Knowledge (SPMK)	Knowledge concerned with the representation and formulation of concepts with appropriate specialised pedagogical techniques. Anticipating what students are likely to think and what they will find confusing, and knowing what teaching approaches are likely to be helpful in relation to particular

		mathematical concepts. Each of these tasks requires an interaction between specific mathematical understanding and familiarity with students and their mathematical thinking and pedagogical knowledge of specific mathematical concepts. For example, knowing the affordances of and appropriate uses of various representations of fractions (e.g., as areas, parts of collections, or points on number lines).
Specialised Mathematics (STMK)	Technological Knowledge	Teachers of mathematics in which the application of technology influences specialised mathematics content require this knowledge. Teachers' selection of technology should fit with the special type of mathematics knowledge. For example, choosing appropriate software to illustrate a mathematical concept.
Specialised Pedagogical (STPK)	Technological Knowledge	The knowledge needed to use technology in pedagogies that support the development of students' understanding. It includes understanding the skill level of students using technology for learning and demands knowledge on how mathematical pedagogies are altered by the application of technology. For example, knowing that using dynamic graphing software to remove the tedium of creating scatter plots can enable students to access more sophisticated ideas about the relationships between variables than would be possible in the absence of technology.
Specialised and Pedagogical (STAMPK)	Technological and Mathematical Knowledge	The application of technology for effective mathematics learning of students. This requires the skill of using technologies, understanding specialised mathematics knowledge to teach mathematics concepts which fit with a selected pedagogy. It also includes an understanding of the advantages of different instructional methods, specialised mathematics knowledge and technologies and combining these knowledge types in the classroom for effective learning of mathematics.

In conclusion, the STAMPK framework proposed provides a promising starting point in understanding, using and explaining the TPACK framework specifically for teaching mathematics. Accordingly, STAMPK situates TPACK in the mathematics classroom by

developing three central components of knowledge necessary for teachers of mathematics in teaching mathematics. It is important to note that identification of elements of the knowledge required by teachers has to be used in understanding and explaining the knowledge required of teachers of mathematics to teach mathematics using technology in the 21st century (Drier, 2001). It emphasises the mathematical knowledge requirements for teaching technology integrated mathematics rather than treating mathematics in the generic framework of TPACK.

3.4. Barriers to the Use of Technology in Teaching

Across Africa and most developing countries, there are many challenges in bringing ICTs into the education process in general and teaching in particular. It is a common misconception that access to technology alone motivates teachers to apply it in their teaching. On the contrary, Hennessy, Harrison, and Wamakote (2010) found that in Sub-Saharan African countries the biggest barriers to the use of ICT include teachers' motivation, technological literacy and confidence levels, pedagogical expertise related to technology use, and understanding the role of the teacher. Getenet, Beswick, and Callingham (2014) indicated that for teachers in Ethiopian schools access to technology is clearly fundamental if they are to integrate technology into their teaching, access alone was not sufficient. Teachers needed to learn how to use available ICTs in their teaching. A similar study of Nigerian secondary school teachers by Tella, Tella, Toyobo, Adika, and Adeyinka (2007) showed a lack of technical support in the schools, and teachers' lack of expertise in using technology, were the prominent factors hindering teachers' readiness and confidence in using technology. Along with these, Unwin (2005) indicated that computer laboratories in educational institutions across Africa are underutilised. Whilst there were some notable exceptions to this generalisation, it seemed that computer laboratories in schools and

higher educational institutions stood idle for much of the time (Tella et al., 2007). As more classrooms become technology rich environments, it is less likely that teachers will perceive the lack of technological resources as a barrier to effective technology integration.

The other major barrier to effective technology integration is teachers' knowledge of technology and pedagogy which is Shulman's (1986) idea of Pedagogical Content Knowledge (PCK) extended into the domain of teaching with technology. The idea of PCK combined with technology knowledge is likely to take the place of lack of technology resources as the main determinant of the extent to which ICT is integrated in teaching (Niess, 2011) because teaching effectively with technology requires TPACK development. Niess emphasised the importance of having integrated knowledge of ICT, pedagogy and content for effective teaching through technology. Studies (e.g., Jimoyiannis, 2010; Koehler, & Mishra, 2009) have shown the ability of teachers to establish the relationship between content, pedagogy and technology, depends largely on the way teachers were taught to integrate technology into teaching and how these components are acquired in PD.

Researchers have classified barriers to integrating ICT in teaching in different ways. The most common classification is at teacher level and school level barriers (e.g., Bingimlas, 2009; Drent & Meelissen, 2008; Pelgrum & Voogt, 2009). Teacher level barriers included technical or pedagogical competences; availability and participation in PD program practices; perceived obstacles; presence of a community of practice; and lack of confidence. School level barriers included lack of access to ICT resources, lack of technical and pedagogical support, lack of effective PD programs and school leadership and support. In many studies, the barriers to integrating ICT in teaching fall into these classifications.

Insufficient PD to support teachers to integrate ICT is another barrier. Countries in Africa supported ICT as an essential component of innovative student centred pedagogy (Hennessy, Harrison, & Wamakote, 2010; Hollow & Masperi, 2009; Ottevanger, Akker, & Feiter, 2007). This stance has implications for school teachers and teacher educators, including the need to equipping school teachers with the necessary skills to integrate ICT in teaching. Along with teacher educators having the skills and knowledge to integrate ICT in their own teaching of pre-service teachers, they also need to prepare teachers to integrate technology in their teaching using a variety of different approaches. It is not sufficient to teach the next generation of teachers in the ways their instructors were taught. Pre-service teachers must encounter the effective integration of technology in the normal course of their learning at CTEs, particularly as ICT is becoming increasingly available in schools. Jacobsen, Clifford, and Friesen (2002) recommended that teacher educators must become familiar with what to do with these new tools and digital media, and create meaningful learning opportunities for pre-service teachers even though they themselves have not experienced such opportunities. Studies (e.g., Steketee, 2005; Unwin, 2005) have included many recommendations about effective ways of supporting pre-service teachers to teach using ICT, and ensuring that pre-service teachers see ICT being modelled by educators in their own teaching, is one means (Li, 2003; Lin, 2008; Taylor, 2004). When teacher educators act as models, pre-service teachers can see the importance of developing and using ICT based lessons in their own teaching. Recent trends in teacher education have emphasised the importance of learning with technology rather than learning about technology. This implies that teacher educators should learn to use ICT to enhance pre-service teachers' learning of mathematics rather than acquiring isolated skills in basic computing applications

(e.g., word processing, database, spreadsheets, or hypermedia) or merely learning a specific programming language (Drier, 2001). Drent and Meelissen (2008) found that a teacher educator, who uses ICT for the enhancement of the learning process of students, also shows students at the same time how ICT can be used in their future teaching. Nevertheless, many teacher educators lack the knowledge needed to do so. One way of improving teacher educators' skills of integrating technology in teaching is creating PD program opportunities from which teacher educators can gain understanding of emerging standards on the use of technology to change their roles and practice in their teaching accordingly. In recognition of the importance of PD, governments in sub Saharan Africa, as elsewhere, are emphasising teacher development as the key to effectively using ICT to enhance teaching and learning (Hennessy et al., 2010). Participating in ongoing PD helps teacher educators to acquire the required knowledge to integrate ICT in teaching (Drent & Meelissen, 2008).

3.5. PD in the Use of Technology

PD programs are necessary to equip teachers with the skills to integrate ICT into their teaching and learning practices effectively (Fitzallen, 2005). Studies investigating PD programs aimed at teachers' use of ICT have indicated that such programs are often focused on acquisition of basic skills in the use of ICT (e.g., Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2012). Furthermore, such PD programs have typically taken place in training centres, in the form of seminars and have been short term (Penuel, Fishman, Yamaguchi, & Gallagher, 2007). This indicates that, with few exceptions, teacher in service PD programs in the use of technology in teaching lack adequate duration, continuity and pedagogical direction. In addition to the need to focus on the pedagogical use of ICT, there is a gap in supporting teachers in relation to

technology use in teaching in ways that are based on subject specific content and pedagogies (Voogt et al., 2012). The following section describes the characteristics of effective PD programs that focus on integrating technology in teaching.

3.5.1. Characteristics of effective professional development programs. More effective PD program strategies are designed to move beyond acquisition of basic ICT skills to conducting ICT focused lessons, the pedagogical aspects of ICT use and eventually helping teachers to adopt appropriate ICT integration in teaching need to be school based, collaborative and continuous (e.g., Borko, 2004; Schibechi et al., 2008; Hea-Jin, 2007). Such PD programs are likely to help teachers exploit additional learning opportunities afforded by ICT and begin to make fundamental changes to their pedagogy (Schibeci et al., 2008). Such programs are supportive of teachers acquiring the appropriate skills for using ICT in teaching (Kalogiannakis, 2010). McKenzie (2002) cited in Schibeci et al. (2008, p. 313) argued that the complex process of preparing teachers to use ICT is best supported by PD programs that focus on pedagogy and adult learning rather than short term training. In addition, O'Bannon and Judge (2004) suggested a PD program in technology must be viewed from a whole school approach, which encourages change over time. A number of studies have examined the characteristics of effective PD programs designed to help teachers use ICT in their teaching. Those shown in Table 3.6 were selected for review in this study because they specifically involved science and mathematics teachers' PD programs with a focus on integrating technology in teaching. Table 3.6 summarises the features of effective PD programs identified by various researchers. It is clear from the table that various sets of characteristics have considerable overlap.

According to Lavonen, Aksela, and Meisalo (2009), informal discussion in small groups and continuous support are vital aspects of PD. Similarly, Borko (2004) emphasised the importance of group formation, collaboration, and ongoing practices as important components of effective PD programs. In addition, rehearsal of classroom practices, active involvement of facilitators, and thoughtful and informed decisions about the context are important aspects of effective PD programs. Van den Akker (1998) suggested three advantages of scaffolding a PD program with exemplar materials. Firstly, it can create a clearer understanding of how to translate the new teaching approach into classroom practices. Secondly, it can provide a concrete foothold for the execution of technology integrated lessons that resemble the intended objectives and thirdly, it can stimulate practitioners to practice the intended teaching approach.

Table 3. 6

Characteristics of Effective PD Programs

Characteristics of effective PD	Studies									
	Lavonen, Aksela, and Meisalo (2009)	Schibeci et al. (2008)	Dexter, Seashore, and Anderson (2002)	Borko (2004)	Hea-Jin (2007)	Looi, Lim, & Chen (2008)	Zaslavsky and Leikin (2004)	Butler et. al. (2004)	Rogers et al. (2007)	Van den Akker (1998)
Collaborative		✓		✓		✓				✓
Continuous		✓		✓		✓				✓
Community/team based	✓		✓	✓	✓	✓	✓	✓		✓
Job embedded		✓	✓		✓	✓				
Happen on field workshop					✓					✓
Supported with exemplar material					✓					✓
Support from facilitator	✓	✓							✓	
Reflective activities			✓	✓		✓	✓	✓		✓
Context based				✓			✓	✓	✓	

Hea-Jin (2007) developed a model of an effective PD program to enhance teachers' conceptual understanding and pedagogical strategies in mathematics and the effective use of ICT. The design of that study incorporated four basic components for effective PD program, systemic support, knowledge building workshops, classroom implementation and application, and building a team. Hea-Jin argued that in order to be effective, teachers need a sustained and ongoing PD program to learn, analyse, and reflect on new concepts and the use of technologies for effective student learning. Real classroom experience, collaborative work and systematic support for effective PD program are also other important aspects (Rogers et al., 2007).

According to Guskey (2003), Loucks-Horsley et al.(2003) and Thompson and Zeuli (1999) cited in Rogers et al. (2007), effective PD programs are characterised by (1) enhancing teachers' content and pedagogical knowledge, (2) providing sufficient time and other resources, (3) promoting collegial and collaborative exchange, (4) establishing procedures for evaluating the PD experience, and (5) conducting site based PD, (6) establishing a well-defined image of classroom learning and teaching, (7) creating a PD design that is based on research and engages teachers as adult learners, and (8) developing a support system and (9) sufficient amount of dissonance to disturb their existing beliefs, knowledge, and experiences with learning and teaching. These effective practices can be readily achieved through the formation of teams (Looi, Lim & Chen, 2008). Teams are considered a suitable PD program strategy (Looi, et al., 2008) on the assumption that knowledge is dynamically constructed as teachers conceive of what is happening to them, talk, and reflect. They are “groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis” (Wenger et al., 2002, in Looi, et al., 2008, p. 4). Such

activities have been shown to benefit teachers by providing opportunities to share ideas with colleagues (Butler, Lauscher, Jarvis-Selinger, & Beckingham, 2004).

The studies cited above underpin a paradigm shift in PD program strategies from traditional one stop trainings, workshops and the like towards more collaborative models (Borko, 2004; Mishra & Koehler, 2006; Zaslavsky & Leikin, 2004). Traditional PD programs have been criticised for resulting in the surface level implementation of instructional principles as opposed to deeply rooted changes in practice. In contrast, collaborative models of PD engage teachers in the joint inquiry about teaching as a means of shifting practice. Furthermore, collaboration can be realised through the formation of teams of teachers for effective and successful collaborative PD (Looi, et al., 2008).

3.5.2. Context analysis and the design of professional development. Context is a complex, multifaceted, perspective dependent concept extending from the specific characteristics of the learning and teaching environment, to disciplinary and personal issues (Benson & Samarawickrema, 2007). According to Morrison, Kemp, and Ross (2004) and Borko (2004), context is a collection of factors that can influence the design of the PD program from a particular group or environment. Context plays an important role in providing rich data for designing real examples, practical content and scenarios (Morrison et al., 2004; Tessmer & Richey, 1997). Understanding context can help the PD program designer gain a better picture of participants need and suggest context based PD program guidelines (Borko, 2004). According to Morrison et al.(2004) and Borko (2004), for example, considering and analysing the context in which the PD program is implemented is an essential component of an effective PD program. Moreover, Wood et al. (2011) indicated that in designing PD programs, context analyses are

considered useful in facilitating outcomes for teachers, and ultimately for students. Smith and Ragan (2005) suggested three themes in analysing context: learner analysis, learning context and learning task analysis. Learners' characteristics and the learning context are used to suggest the learning task which in this case was the PD program (Smith & Ragan, 2005). Table 3.7 shows the three aspects of context analysis and guiding issues to be considered as suggested by Smith and Ragan (2005).

Table 3. 7

Context Analysis Aspects and Guiding Issues

Context (Smith & Ragan, 2005)	Guiding issue (Smith & Ragan, 2005)
Analysing the learners	<ul style="list-style-type: none"> • Learners' general characteristics • Learners' prior knowledge • Age • Beliefs towards the subject matter • Characteristics of learners' preferences, attitudes, interest
Analysing the learning context	<ul style="list-style-type: none"> • Determine whether there really is a problem • Determine whether the cause of the problem is related to educators performance due to a particular problem
Need assessment	<ul style="list-style-type: none"> • Determine whether the solution to the achievement/performance problem is learning • Determine whether the instruction for these learning goals is currently offered • Are there existing curricula into which this piece of design must fit?
Describing the learning environment	<ul style="list-style-type: none"> • What hardware is commonly available in the potential learning environment? • The characteristics of the classes and facilities that will use the new PD program results • The characteristics of the school system
Learning task analysis	<ul style="list-style-type: none"> • Write learning goals • Determine the types of learning goal • Conduct an information-processing analysis of that goal • Conduct a prerequisite analysis • Determine the type of learning of the prerequisites • Write learning objectives

According to Smith and Ragan (2005), the analysis of learners' characteristics is an important aspect of instructional design in general and PD program design in particular. In particular, analysis of learners' specific prior knowledge is a key feature to consider (Hailikari, Katajavuori, & Lindblom-Ylänne, 2008).

As part of the context analysis, the environment in which the PD program is to be conducted should be analysed to gain an insight about the existing condition in relation to the PD program (Tessmer & Richey, 1997). According to Smith and Ragan (2005), the analysis of the learning context involves two major components including the substantiation of a need for the PD program and a description of the learning environment in which the PD program will be implemented. After understanding the learning context and the learner context, the next step is to identify an appropriate PD program to address the above context. Smith and Ragan (2005) indicated that the principle steps in performing a learning task analysis are to write learning goals, determine the types of learning goals, conduct an information processing analysis of that goal, conduct a prerequisite analysis and determine the type of learning of the prerequisites, write learning objectives for the learning goals and each of the prerequisites and write test specification.

3.6. A Synthesis of the Literature Reviewed

The last section provided a detailed account of the literatures related to the study. This section provides a summary of the literature reviewed in terms of the overall objective of the study and conceptualises the overall themes of the study. Moreover, the gaps identified in the literature reviewed are summarised.

3.6.1. Teacher educators. Despite the wealth of commentaries on teacher education programs, there is little empirical research focused on teacher educators themselves (Beswick, Chapman, Goos, & Zaslavsky, 2012; Murray & Male, 2005; Ottenbreit-Leftwich et al., 2012). A question seldom discussed in the literature is in what extent should a teacher educator be competent so that pre-service teachers can learn from teacher educators? Although teacher education is considered important to the quality of teachers, very little is known about the professional quality of teacher educators. Hence, there is a need to study teacher educators, the role of the teacher educator, and to rethink the kinds of knowledge and skills teacher educators ought to have for effective teaching of pre-service teachers. This study is part of the effort to support teacher educators in the use of technology in teaching and enabling them to be role models for pre-service teachers. There are few studies on PD programs offered to teacher educators with a few of these focused on the PD program needs of newly appointed teacher educators, on the effectiveness of PD program activities carried out for the teacher educators, and on the difficulties they experienced (Kabakci, Ferhan Odabasi, & Kilicer, 2010; Murray & Male, 2005). A desirable professional competency of teacher educators that has been identified is the ability to model explicitly for pre-service teachers the thoughts and actions that underpin their teaching approaches (Loughran & Berry, 2005). This study was aimed at assisting teacher educators through PD program involvement to effectively use technology in their teaching in order to enable pre-service teachers to learn about using technology in their own practice.

3.6.2. Knowledge requirements in teaching with technology. Many studies have used Koehler and Mishras' generic TPACK framework as a basis for the knowledge required for teachers using technology in teaching. Few studies (for exception, see Guerrero, 2010; Jang &

Chen, 2010) have related the concept of TPACK to particular subject matter content and pedagogy, and PCK. Voogt, Fisser, Pareja Roblin, Tondeur, and van Braak (2012) conducted a systematic literature review of TPACK based on 55 peer reviewed journal articles and one book chapter published between 2005 and 2011. Creating an understanding of the subject specific use of TPACK in teaching of mathematics through technology was a gap identified in this study and resulted in the development of the STAMPK framework as described in Section 3.4. Exploring the potential of understanding the STAMPK framework from the perspective of teaching pre-service teachers to teach technology integrated mathematics could help mathematics teacher educators to improve their teaching and hence the preparation of pre-service teachers.

3.6.3. PD program strategies. Although PD programs are taken as essential to enhancing teacher efficacy, they are often organised in traditional and pre-packaged forms. Studies (e.g., Borko, 2004; Putnam & Borko, 1997) have indicated that traditional models of PD have not been particularly successful in helping teachers to find ways to integrate technology into their teaching and teachers are not comfortable with such PD programs. In recent years, PD for teachers has been considered a long-term process that includes regular learning opportunities and experiences planned systematically with involvement of participating teachers. Traditional PD programs have been criticised for being ineffective because they are often organised as fragmented and superficial workshops or seminars irrespective of participants' involvement in a design process (e.g., Borko, 2004; Butler et al., 2004). On the other hand, studies (e.g., Borko, 2004; Hea-Jin, 2007; Rogers et al., 2007; Zaslavsky & Leikin, 2004) have indicated that PD programs which emphasise the importance of involving participants in a PD program design process, team formation, collaboration and continuous practices, and are job embedded and value

the role of facilitators are increasingly regarded as effective. Several characteristics of the newer forms of effective PD programs have informed this study.

Teacher educators in particular, need PD programs in the effective use of ICT in order to keep up with the changes and developments in ICT and to be able to model appropriate use of ICT for teacher candidates (Kabakci et al., 2010). There is a gap in the knowledge of how best to assist teacher educators to use technology to influence pedagogy and content in a certain context. In a review of PD programs on technology use in teaching, it was argued that researchers' interplay of technology, pedagogy and content knowledge should be emphasised. Technology, pedagogy and content by themselves, however, are diverse. There are different technologies that can facilitate teaching, such as spreadsheets, GeoGebra, and Microsoft Mathematics and it is challenging to keep up to date with these as well as with new emerging technologies. It could be unrealistic to attempt to equip teacher educators in relation to all available technologies and pedagogies. There is a range of pedagogical practices which can facilitate learning of students (e.g. problem solving, inquiry learning, etc.). The teacher is a designer tasked with selecting the appropriate pedagogy and technology for the particular content to be taught. Hence, this study was aimed at devising a PD program strategy to enhance teacher educators' STAMPK which would help them design appropriate pedagogy and technology in mathematics teaching. In doing so, this PD program took into account the features of effective PD as identified in the literature reviewed in this chapter.

3.6.4. Context. Context is one of the first variables considered in designing the first PD program prototype. As previously mentioned (Morrison et al, 2004), context is a collection of factors that can inhabit or facilitate designing a PD program. In this study, context analysis was

considered a primary aspect because it influences every aspect of the learning experience including a PD program. Analysis of context provides rich data for designing real world examples and PD program scenarios (Morrison et al., 2004). Investigating the characteristics of context for a PD program design process makes the content concrete, realistic and helps the audiences understand how it can be applied on the job. For the purpose of this study 2 of the 3, the contexts mentioned by Smith and Ragan (2005) are considered, namely the learning context and the learner context whereas the third task assessment is considered as a PD program in this study. The purpose of this phase is to help the PD program designer gain a thorough understanding of all these components in order to design a context based PD program. Context analysis can be used to design a PD program following the procedure shown in Figure 3.7.

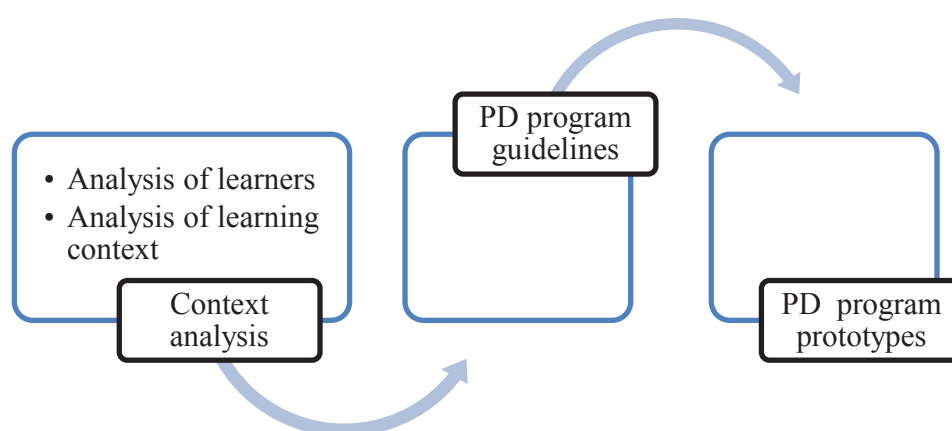


Figure 3. 7. Design process of the PD program prototype.

3.7. Chapter Summary

This chapter has explored the literature detailing concepts in relation to the use of technology in teaching mathematics. The review indicated that increased availability of technology resources does not guarantee increased rates of effective integration of technology; rather the integration of technology into teaching demands specific knowledge of teachers that

can be enhanced through PD program participation. Moreover, the review presented in this chapter posited that PCK combined with technology knowledge in the context of mathematics teaching, is likely to take the place of a lack of technology resources as the main determinant of the extent to which technology is integrated successfully in teaching.

The literature reviewed was used to identify aspects of the teacher educators' context relevant to their current practices of technology integrated teaching. This was used to design a PD program to support the integration of technology into their teaching, and to evaluate the impact of the PD program.

As indicated in Section 3.3, Pedagogical and Content Knowledge (PCK) in mathematics is an essential element for teaching mathematics. As technology is used in classroom teaching, TPACK is an important factor in the successful integration of technology in teaching effectively. Section 3.3 described how the two frameworks (the TPACK framework and Ball et.al and colleagues' model) were used to develop a framework of knowledge required to teach technology integrated mathematics called the STAMPK framework. This review also showed that mathematics teacher educators would benefit from participation in a PD program designed around contextual realities, that were continuous, collaborative and team based, and aimed at enhancing their technology integrated mathematics teaching practices. Research reviewed in this chapter was considered and used for three main purposes. First, to identify the context of the teacher educators' current practices of technology integrating teaching, second, to inform the design of a PD program to support teacher educators to integrate technology in their teaching, and third to evaluate the impact of the PD program designed for teacher educators' technology integrated teaching.

Based on the research discussed, the next chapter will consider the methodology involved in this study. Both the quantitative and qualitative data collection methods will be introduced. Participant recruitment, instruments and methods for the data analysis, including the use of SPSS software, and thematic analysis followed by data analysis of qualitative data will also be discussed.

Chapter 4 Methodology

The previous chapter examined the relevant literature and theories, which informed the overall design of the study. It reviewed the knowledge required to integrate technology in teaching mathematics in particular and the characteristics of effective Professional Development (PD) practices. Chapter 3 also presented conceptualisation of Technological Pedagogical Content Knowledge (TPACK) for teaching mathematics. This chapter provides an overview of the research approach, and details of the quantitative and qualitative data collection. It outlines the methodological principles of the study, which was underpinned by a mixed method approach based on Educational Design Research (EDR). The design of the research instruments is detailed in the chapter along with the data analysis tools and methods.

4.1. Research Objective and Questions

In Ethiopia, mathematics teacher educators are encouraged to integrate technology into their teaching. Less importance, however, is placed on providing PD programs which focus on the use of technology in teaching. The objective of this study was to design, develop and evaluate a job embedded PD program that supported mathematics teacher educators to integrate technology in their teaching in Ethiopian Colleges of Teacher Education (CTEs). As outlined in Chapter 1, Section 1.3, the following research questions that guided the overall objective of the study.

1. What competencies do teacher educators currently have in relation to integrating technology into the teaching of mathematics education?
2. What are the factors that influence teacher educators' integration of technology into teaching?

3. How might an intervention support the development of teacher educators' skill in relation to integrating technology into teaching?
4. What competencies can teacher educators demonstrate in relation to integrating technology into teaching after participating in a PD program?

4.2. Research Approach

This study adopted a mixed method research approach, which used both quantitative and qualitative methods to gather and analyse data. The mixed method approach was chosen for two main reasons: Firstly, to adopt the strengths of both methods, and potentially offset their respective weaknesses (Leech & Onwuegbuzie, 2010) and secondly, because the study involved an intervention, it was important to assess the fidelity of the intervention and maximise the validity of interpretations of the findings using both methods (Leech & Onwuegbuzie, 2010).

In addition to using qualitative and quantitative research methods to analyse the data, the study used an Educational Design Research (EDR) approach as described by McKenney and Reeves (2012) in which the inquiry is focused on understanding the responses that a specific PD program process engenders. EDR evolved near the beginning of the 21st century as a practical research methodology that provided a bridge between research and practice in the classroom context (Anderson & Shattuck, 2012). The terms “design-research” (Oh & Reeves, 2010), “development research” (Conceição, Sherry & Gibson, 2004), “design experiment” (Brown, 1992), and “educational design research” (McKenney & Reeves, 2012) have been used to describe the same methodology, but the term EDR has been used in this study.

Brown (1992), who is credited with first developing EDR, noted, “an effective intervention should be able to migrate from our experimental classroom to average classrooms operated by

and for average students and teachers, supported by realistic technological and personal support” (p. 143). Following Brown’s suggestion of EDR as the best methodology for designing interventions to solve classroom problems, studies have further defined and described the use of EDR. Anderson and Shattuck (2012) defined EDR as a methodology designed to increase the impact of educational research on practice, noting that educational research on the whole has had limited effect on practice. Likewise, Wang and Hannafin (2005) defined EDR as a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real world settings. Thein, Barbas, Carnevali, Fox, Mahoney, and Vensel (2012), and Anderson and Shattuck (2012) listed several key elements that set EDR apart from other educational research paradigms. These include being situated in real educational contexts; focusing on the design and testing of a significant intervention; using mixed methods, involving multiple iterations; involving a collaborative partnership between researchers and practitioner; evolution of design principles; and a practical impact on practice.

EDR has been applied in a number of studies. For example, Thein et al. (2012) used EDR to investigate the effectiveness of instructional practices for teaching multicultural literature through a collaborative and iterative process of inquiry driven by theoretical principles. Hakkarainen (2009) showed its applicability in education to design, implement and refine a problem based learning course on educational digital video use and production. Similarly, Wang and Hannafin (2005) indicated its effectiveness to design technology enhanced learning environments. Further, using EDR, Reeves, Herrington and Oliver (2005) explored the various

incentives for conducting research on the impact of computing and other technologies in higher education.

In this study, EDR was used to design a PD program and study teacher educators' knowledge of technology integrated mathematics teaching practices. As suggested by the Design-Based Research Collective (2003), EDR provided an important methodology for understanding the when, how, and why of educational interventions in work practice contexts. This design is helpful to express specific theoretical claims about teaching and learning, and clarifies understanding of the relationships among educational theory, planned intervention, and practice (Design-Based Research Collective, 2003). For most of its history, research in education has influenced practice loosely and indirectly. Researchers taught theories and findings to educators, teachers, professionals, leaders, and researchers in training and they, in turn, applied the theories. In practice, however, theory and research findings often functioned as little more than slogans for reforms (Walker, 2006). EDR, however, seems to be a means to analyse a learning problem in ways that could lead to quite specific ideas for intervention relevant to a particular context. In this regard, McKenney and Reeves (2012) indicated that EDR conducted for creating a PD program package is aimed at primarily solving problems in practice. Hence, in this study, the researcher's analysis of a learning problem prompted quite definite ideas for a PD program approach. The researcher then designed a PD program that included the creation of specific teaching and learning materials and methods designed to realise participants' learning gains predicted by theory and research. The actual PD program design and delivery is explained in Chapter 5, Section 5.2.

In relation to the design and delivery of PD program, Nieveen (2009) emphasised the purpose of using EDR in educational setting to design high quality PD and explained how it works in practice. A PD program influences practice through systematic analysis, design, and evaluation of the PD program (Nieveen, 2009; Plomp, 2009). For this study, a PD program was designed as a means to influence teacher educators' practice of technology integrated teaching. In the design process of the PD program, pre-service teachers' and teacher educators' responses to the PD program were examined as suggested by theory in relation to the context. The EDR approach was implemented because of its appropriateness to improving educational realities in their particular context directly through PD program opportunities created by the study itself and indirectly through design principles tested in practice (Van den et al., 2006). In conducting EDR, the study followed three interrelated phases suggested by Plomp (2009). The phases were:

- Phase 1: Preliminary research,
- Phase 2: Prototyping, and
- Phase 3: Assessment

During Phase 1, a context and problem analysis along with the development of a conceptual framework based on literature review was conducted (Kelly, 2006, Plomp, 2009). As suggested by Plomp (2009), the development of a conceptual framework for the study was basic at this phase. As a result, the activities performed were the development of the conceptual framework of the study and the design of the first PD program prototype based on the context analysis. The conceptual framework was developed by reviewing relevant theories which pointed the way to formulate a framework for the knowledge of mathematics teacher educators to integrate technology in their teaching as reported in Chapter 3, Section 3.3, and associated

instruments to measure this kind of knowledge in Section 4.5 of this chapter (see also Getenet & Beswick, 2013). The PD program guidelines were formulated and suggested through the context analysis using Smith and Ragan's (2005) categories of context to design instructional material. The initial context analysis was based on themes around the domains of context suggested by Smith and Ragan (2005), as shown in Table 4.1.

Table 4. 1

Themes Used for Context Analysis in this Study

Context	Data collected
Analysing the learners (pre-service teachers and teacher educators)	<ul style="list-style-type: none"> • Demographic data about the learners, including number of participants and teaching experience • Teacher educators' beliefs about the use of technology in teaching, perceived proficiency in technology, their current STAMPK, the value given to technology integrated teaching, kind of the PD program attended and challenges in using technology in teaching mathematics • Pre-service teachers' perceived proficiency assessment of technology, belief in the use of technology in teaching, the value given to technology in relation to learning and the factors influencing learning with technology
Analysing the learning context	<ul style="list-style-type: none"> • Kind of PD program teacher educators required to facilitate use of technology in their teaching
Needs assessment	<ul style="list-style-type: none"> • Previous PD program attended by teacher educators
Describing the learning environment	<ul style="list-style-type: none"> • Availability of technologies and classroom facilities • The CTE department's policy on the use of technology in teaching

Phase 2 involved the design of guidelines, optimising prototypes through two cycles of design, formative evaluation and revision as suggested by Kelly (2006) and Plomp (2009). Only two cycles were conducted due to time limitations. As Plomp (2009) indicated, this phase was an iterative design phase consisting of repetitions of the research with formative assessment aimed at improving and refining the PD program. During this phase, the quality of the PD program was assessed with respect to its validity, practicality and effectiveness (Nieveen, 2009). Validity was assured through the design of the PD program based on the state of the art of the existing knowledge (content validity), and consistently linking various components of the PD program to each other (construct validity). Practicality was achieved through testing the extent to which users of the PD program considered it as appealing and usable in the context (Plomp, 2009) at the later phase. Practicality was tested by assessing and comparing mathematics teacher educators' technology integrated teaching before and after participating in the PD program in the later phase. Effectiveness was inferred from pre-service teachers' feedback and reflective feedback on teacher educators' new technology integrated teaching approaches.

Phase 3 consisted of summative evaluation to assess whether the PD program met the pre-determined objectives. According to Plomp (2009), Phase 3 often results in recommendations for improvement of the intervention. Further, this phase often explores transferability and scaling along with effectiveness (Kelly, 2006). As a result, at this stage, summative evaluation was undertaken to identify the effectiveness of the PD program on teacher educators' technology integrated mathematics teaching practices by comparing before and after results following their participation in the PD program process. To illustrate this phase, samples of two lessons are

presented in Chapter 5, Section 5.3 that demonstrate the effectiveness of teacher educators' technology integrated mathematics teaching.

4.2.1. The role of the researcher. One of the challenges of the EDR process is the question of where to place the researcher on an epistemological continuum: towards the subjective side or closer to an objectivist stance. According to Van den et al. (2006), rather than pretending to be an objective observer, the researcher must be careful to consider his/her role in influencing and shaping the phenomena under study. In this study, the researcher was both a researcher and a designer immersed in the research context and involved intensively in interaction with participants. In order to maximise objectivity and neutrality in managing the research processes, and designing and implementing the PD program in collaboration with participants, it was important to ensure that these processes were undertaken systematically as recommended by Wang and Hannafin (2005). The researcher engaged in the creative activity of developing and suggesting a PD program informed by existing scientific knowledge, context analysis and revision of the PD program in a similar fashion to that described by McKenney and Reeves (2012). Figure 4.1 shows the role of the researcher in each phase of the study. A fuller description of the researcher's roles follows the figure.

4.2.1.1. PD program designer. According to Wang and Hannafin (2005), designers in EDR identify resources relevant to their project needs using literature from multiple sources and conduct an analysis of the context to design an appropriate intervention. As a result, after an intensive analysis of the context, the PD program guidelines were suggested. The researcher's position in this phase was relatively objective. These guidelines supported the initial launch of the PD program, which later developed and improved through alteration process.

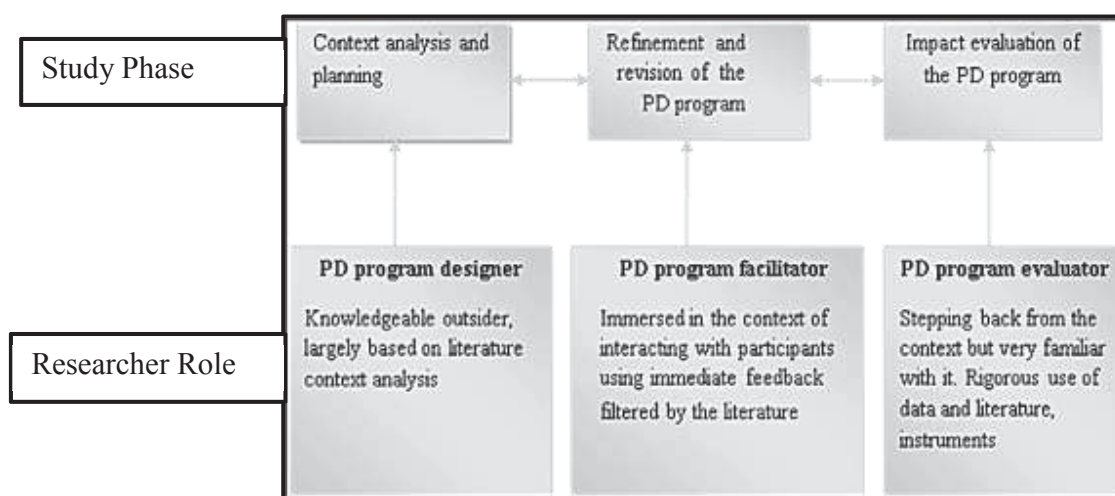


Figure 4. 1. The researcher role in the study.

4.2.1.2. PD program facilitator. The facilitation role was relevant during the intervention process and included arranging a discussion platform for the initial PD program design, initiating the first PD program meeting, and forming discussion teams throughout the intervention process. The involvement of a researcher in EDR as a facilitator and initiator of the research ideas is a particular characteristic of EDR (e.g., Anderson & Shattuck, 2012; Barab & Squire, 2004; McKenney & Reeves, 2012). This required the researcher to articulate clearly his role in the research process prior to beginning of the PD program. In this phase, the researcher was immersed in the process in a more subjective position than in the previous phase. The researcher supported the teacher educators' technology integrated teaching when requested only including answering questions about the STAMPK framework and deliberately took a backward stance to see how the process worked when driven by teacher educators.

4.2.1.3. PD program evaluator. Based on Kelly's (2006) recommendation the researcher evaluated the effectiveness of the PD program on teacher educators' technology integrated teaching practices. In this role, the researcher used relevant data and literature to determine the extent to which the intervention met the pre-determined specifications using

designed instruments. During this phase, the researcher was stepping back from the context, but remained very familiar with it.

4.3. Data Collection

The data collection instruments were questionnaires, interviews, observations and focus group discussions (including workshops). Both qualitative and quantitative data were collected. The following sections detail procedures for research site selection, participant recruitment, sampling, and research instruments.

4.3.1. Research site. The research sites for the study were two Colleges of Teacher Education (CTEs) with pseudonyms College 1 and College 2. Both were government owned and administered by Amhara National, Regional State in Ethiopia. They were among the largest CTE institutions in the country that graduate primary school teachers with an approximate enrolment of 5000 students. Both had similar organisational structures and comprised the same departments. In each, the department of mathematics existed to meet the demand for primary school mathematics teachers in the region and the country. Both CTEs were selected as study sites because the researcher had experience working with staff members of these CTEs. Because one of the distinctive characteristics of EDR is a deep understanding of the context (Cobb, 2003), this prior knowledge of the context was an asset to the study's effectiveness. Following formal University of Tasmania ethics approval, therefore, the researcher had firstly to get permission from the regional government. Based on a formal support letter from the University of Tasmania (see Appendix B) the Ethiopian regional education office endorsed the research to be conducted in the CTEs (see Appendix C). The CTEs then approved the study to be conducted in the respective departments.

4.3.2. Participant recruitment and sampling. The research involved the participation of 16 teacher educators, 120 elementary pre-service mathematics teachers, and four ICT coordinators before teacher educators participated in the PD program. The same number of teacher educators and ICT coordinators with an additional six pre-service teachers (126) were involved after teacher educators participated in the refined PD program. McKenney and Reeves (2012) and Plomp (2009) suggested that an EDR process should consider collaboration of all stakeholders affected by the process while recruiting research participants. These collaborators include target groups (e.g., teachers and students), stakeholders (e.g., administrators and parents) and experts. In this study, mathematics teacher educators, and mathematics pre-service teachers were targeted groups and ICT coordinators were involved as experts. The ICT coordinators were helpful in facilitating the research process and reflecting on teacher educators' practices in using technology in teaching. Moreover, the ICT coordinators supported the effort made in investigating the context of the CTEs.

After receiving permission to conduct the research at CTEs, the researcher made formal contact with teacher educators and department heads. As a result, pre-service teacher participants were invited in collaboration with teacher educators. In the process, the researcher always ensured that there was no coercion from teacher educators on pre-service teachers to participate in the study. The pre-service teachers' participation in the study was voluntary. To ensure voluntary consent, the distribution of information sheets and consent forms (see Appendix D), and collection of signed consent forms was undertaken according to the following procedure.

The researcher formally contacted the CTEs after approval from the regional education office. The academic and research Vice Deans were asked to distribute the information sheet and

consent form to teacher educators. The completed consent forms and questionnaires were forwarded directly to the researcher. The information sheet invited teacher educators to show their willingness to participate in a questionnaire. Furthermore, for those teacher educators willing to participate in the questionnaire, it requested participants to indicate their willingness to participate in one or more of the study activities including an interview, professional learning workshop, focus group discussion, anonymously completing a final questionnaire, and observation sessions. Participants who were interested in participating in one or more of the study activities were invited to provide their phone number or email. When the number of interested participants to participate in one or more of the activities were greater than the required number, additional criteria were included such as their availability and ability to explain ideas. For example, 35 pre-service teachers were interested in participating in the interview; however, only 10 of them were selected with the help of teacher educators for the interview based on their ability to explain ideas clearly.

In a parallel process, participant teacher educators who agreed to participate in the study were asked to distribute the information sheets and consent forms for pre-service teachers, which invited them to participate in a questionnaire. The questionnaire allowed pre-service teachers to indicate their willingness to participate in one or more of the activities including an interview, focus group discussion, observation sessions, and completing a final questionnaire. Participants who were interested in taking part in one or more of these activities were invited to provide their phone number or email. In addition, the Academic and Research Vice Deans of the CTEs were asked to distribute the information sheet and consent form for the ICT coordinators to participate in an interview. The ICT coordinators who were interested in participating in the first interview

were invited for another interview and professional learning workshops. In the study, all mathematics teacher educators at the two CTEs were involved. Only first and second year pre-service mathematics teachers participated in the study because third year pre-service teachers were off campus for practice teaching. Table 4.2 shows the number of participants involved in different activities of the study both before and after the teacher educators participated in the refined PD program.

Table 4. 2

Participants in the Study

			Teacher educators					Pre-service teachers			ICT coordinators		
			Questionnaire	Interview	Observation	Focus group discussion	Workshop	Questionnaire	Interview	Focus group discussion	Interview	Workshop	
After the PD Program	Before the PD program	Gender	M	13	4	4	4	13	55	5	-	3	3
			F	3	2	2	2	3	65	5		1	1
		College	1	7	3	3	5	7	57	5		2	2
			2	9	3	3	5	9	63	5		2	2
	After the PD Program	Gender	M	13	4	4	4	13	67	5	6	3	3
			F	3	2	2	2	3	59	5	4	1	1
		College	1	7	3	3	5	7	66	5	5	2	2
			2	9	3	3	5	9	60	5	5	2	2

The same teacher educators and pre-service teachers participated in the interviews, focus group discussion (only for teacher educators) and observation sessions of the study both before and after the teacher educators participated in the PD program. The focus group discussion with pre-service teachers was conducted only after teacher educators participated in the PD program.

4.4. Research instruments

The study employed both quantitative and qualitative methods to gather and analyse data. Creswell (2009) recommended that the combination of quantitative and qualitative methods enables the researcher to collect broader and more significant ideas and gain deeper insights into the views of the participants within the research area. Along with this, McKenney and Reeves (2012) and Kelly (2006) suggested that interview, focus group discussions, observations, questionnaire, tests, logbooks and documents analyses are the recommended instruments to use in conducting EDR. In the current study, the data were collected using questionnaires, interviews, focus group discussions, and observations. The following subsections describe in detail each instrument used to collect data.

4.4.1. Quantitative data: Questionnaires and an observation checklist. Two kinds of questionnaire were prepared and distributed during Phase 1 (Preliminary research) and Phase 3 (Assessment) for both teacher educators and pre-service teachers. An observation checklist was also used before and after teacher educators participated in the refined PD program. The following section provides a description of these instruments.

4.4.1.1. Teacher educators' questionnaire. The questionnaire (see the full questionnaire in Appendix E) was administered in the preliminary context analysis (Phase 1). Both open ended questions and Likert scale questions were asked and the questionnaire was

distributed to 16 mathematics teacher educators. The questionnaire consisted of five different parts. Part I invited participants to provide their demographic data, including their age, teaching experience, qualification and gender. Part II contained questions related to general technology use and availability (not available, limited access, not accessible for teaching purpose, and not accessible). Part III contained items adapted from Schmidt et al. (2009) and modified to measure mathematics teacher educators' agreement about their Specialised Technological and Mathematics Pedagogical Knowledge (STAMPK) (Getenet & Beswick, 2013) in a continuum (1 = Strongly Disagree to 5 = Strongly Agree). The total items in this category were 41 in which each component of STAMPK had multiple items to measure the construct. For example, there were seven items to measure teacher educators' Technological Knowledge (TK). An example of items of STAMPK is provided in Section 4.5. Part IV contained items adapted from Ropp (1997) which invited teacher educators to show their agreement with items addressing Technology Proficiency Self Assessment (TPSA) in their daily activities. The 21 items were rated on Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). The items of TPSA included I feel confident that I could send an e-mail to a friend, subscribe to a discussion list, and describe different software programs that I would use in my teaching. Finally, Part V contained open ended questions asking about the types of PD programs they had attended previously, the type of PD programs they would like to attend, and their knowledge in relation to each aspect of the STAMPK framework. The questionnaire administered at the evaluation stage (see the full questionnaire in Appendix F), Phase 3, contained all parts included in the questionnaire administered at Phase 1 except for Parts II, IV and V (e.g., PD programs they had attended

previously and kinds of PD programs they required). Examples of the items and the instrument development process are described in Section 4.5.

4.4.1.2. *Pre-service teacher questionnaire.* The questionnaire for pre-service teachers consisted of different parts in the two phases of the study: the preliminary phase, Phase 1 and the evaluation phase, Phase 3. The questionnaire distributed in Phase 1 contained four parts and was completed by 120 pre-service teachers (see Appendix G). The first part, Part I, requested demographic data, including gender, age range, and year level in CTE and teaching experiences. Part II comprised questions related to technology use and availability (availability was rated by not available, limited access, are not accessible for teaching purpose, free Access) and frequency of use of technologies in their learning, (rated by never, once or twice per semester, about once every month and at least once per week). Part III contained 16 items which were adapted from Ropp (1997) to determine pre-service teachers' TPSA in relation to using technology in their daily lives and were same as to the items distributed to their teacher educators. Part IV contained open ended items asking about the challenges with using technologies and a description of a specific episode where their teacher educators effectively demonstrated combining content, technologies, and teaching approaches in a classroom lesson. The full questionnaire distributed in Phase1 can be found at Appendix G. The questionnaire completed by 126 pre-service teachers after their teacher educators participated in the PD program in Phase 3 was similar to the questionnaire distributed during Phase1 except Parts II and III which were not included when the questionnaire was distributed in Phase 3. The items included in this phase asked about respondents' frequency of use of a range of technological

devices in learning mathematics. The full questionnaire distributed in Phase 3 can be found at Appendix H.

4.4.1.3. An observation checklist. An observation checklist was used to evaluate teacher educators' technology integrated mathematics teaching practices before and after their participation in the PD program. The checklist was adapted from Agyei and Voogt (2011) and modified to evaluate mathematics teacher educators' technology integrated mathematics teaching practices based on STAMPK constructs. The checklist contained 20 items to measure each STAMPK construct on a scale of 3 = observed; 2 = partly observed and 1=Not observed. A space was provided to describe observed practices in each component of STAMPK. For example, if a teacher educator scored a modal value of 2 from the three items addressing the TK construct, the teacher educator had no technical problems in using the technology but was observed having some irregularities using it to teach the mathematical concept. A modal value of 3 (observed) meant the teacher educator used the technology effectively without any challenges or irregularities. The observation was conducted with six teacher educators during Phase 1 and six teacher educators in Phase 3 with two observations completed in each phase. Details about the development process of the observation checklist are provided in Section 4.5.1.

4.4.2. Qualitative data. The qualitative data were collected using interviews, focus group discussions including during workshops, and open ended data responses obtained through the questionnaires. Qualitative data were also collected as part of an observation checklist as indicated in Section 4.4.1.3.

4.4.2.1. Interviews. Semi-structured interviews were conducted with six teacher educators, four ICT coordinators and 10 pre-service teachers before and after the teacher

educators participated in the PD program. As the study adopted a semi-structured interview approach, questions were prepared in relation to the research contents prior to the interviews. As recommended by Diefenbach (2009), these questions were few in number but allowed for in-depth probing of views, attitudes, thoughts, beliefs, knowledge, reasoning, motivations and feelings that were associated with the research topic. Interview schedules (see Appendix I) were prepared for each group. The interviews were designed to enrich and validate the quantitative data from questionnaires and the observation checklist. The detailed contents and development of the questions is provided in Section 4.5.2. Examples of interview questions are provided in Section 4.5.2.

4.4.2.2. Focus group discussions. Focus group discussions were conducted with six teacher educators and 10 pre-service teachers. The same four teacher educators were involved both in the interviews and focus group discussions. As recommended by Gill, Stewart, Treasure, and Chadwick (2008), the focus group discussions were used for generating information on collective views of pre-service teachers and teacher educators, and the meanings that lie behind those views. Furthermore, these were used to generate a rich understanding of participants' experiences and beliefs about technology integrated mathematics teaching. The focus group discussion complemented the interviews by creating an opportunity for participants' to provide collected views and arguments on ideas. The focus group discussions with teacher educators were conducted before and after the teacher educators participated in the PD program, whereas the discussions with pre-service teachers were conducted only after the teacher educators had participated in the refined PD program. A discussion protocol (see Appendix J) was prepared for each group to guide the discussion and follow up the discussion to the point objectives of the

focus group discussion (Flick, 2009). Examples of focus group discussion questions are provided in Section 4.5.2.

4.4.3. Summary of data collection. Table 4.3 shows a summary of the study linking participants, activity, instrument used, and phase of the study with a follow up description of each phase.

Table 4. 3

Summary of Participants, Activity, Data Collection, Instrument Phase of Study and Appendix

Participants	Activity	Data collection	Instrument	Phase/s	Appendix
Pre-service teachers	Interviews	Audio recording	Interview Schedules	1, 3	I
	Focus group discussions	Audio recording	Discussion Schedules	3	J
	Surveys	Questionnaire	Questionnaires	1, 3	G, H
Teacher educators	Surveys	Questionnaire	Questionnaires	1, 3	E, F
	Interview	Audio recording	Interview Schedules	1, 3	I
	Focus group discussions	Audio recording	Discussion Schedules	1, 3	J
	Observations	Video recording and checklist	An observation Checklist	1, 3	K
	Workshops	Video recording		2, 3	
ICT coordinators	Interviews	Audio recording	Interview Schedules	1, 3	I
	Workshops	Video recording		2, 3	

During Phase 1, the data were collected through interviews, questionnaires, focus group discussions and observation sessions. In this phase, the mathematics teacher educators' TPA and their practice of technology integration in teaching was investigated. This phase explored the existing problems related to mathematics teacher educators' knowledge in relation to each type described in the STAMPK framework and factors influencing their use of technology in teaching such as availability of resources, administrative support and others. In addition, at this stage, the characteristics of the PD program were identified. Interviews were carried out with six teacher educators, 10 pre-service teachers, and four ICT coordinators. Questionnaires were completed by 120 pre-service teachers and 16 teacher educators. To understand in depth the nuances of opinion of participants and to collect data from multiple individuals simultaneously (Onwuegbuzie, 2009) a focus group discussion was carried out with six teacher educators. Classroom observations were conducted with the same six teacher educators. Each observation lasted from 50 to 120 minutes. The observations were recorded using an observation checklist. This phase required a total of 3 weeks to complete in both sites.

During Phase 2 of the study, the researcher, in collaboration with experienced mathematics teacher educators, designed a PD program session and exemplar support materials (the exemplar material will be discussed in Chapter 5, Section 5.3 and shown in Appendix N). The PD program designed, based on contextual analysis, expert review, and review of literature, was implemented after the research participants reviewed the PD program during the initial workshop and interviews. The exemplar material which was distributed to the teacher educators by the researcher before the initial workshop assisted the teacher educators by suggesting procedurally specific activities and tasks with respect to lesson planning such as lesson preparation, topic,

objectives, teacher educators and pre-service teachers' activities, time allotment and assessment techniques while using technology. Before designing the material, the researcher and teacher educator participants were exposed to a range of important issues of technology integration in teaching, design principles, and exemplar support materials through a workshop. The professional learning workshop was designed to motivate the participants, and explain the PD program guidelines (see detail in Chapter 5, under Section 5.3). This phase was a time where teacher educators gained insight into how to integrate technology into their teaching and could make a decision about whether to be involved in the PD program. The PD program was designed in collaboration with the teacher educators. It lasted for one and half academic semesters over a period of 5 months. In Phase 3 of the study, the overall impact of the PD program on improving the teacher educators' experiences of and pre-service teachers learning was assessed in a summative form. Because this was the evaluation phase, all activities carried out in Phase 1 were repeated. In addition, the interview with teacher educators was focused on the whole intervention, and they were asked about their experiences of the PD and their thoughts regarding its operation, process, and outcomes, and about any changes they perceived in themselves particularly their use of technology integrated teaching because of their involvement in the refined PD program process. This and the other phases were conducted concurrently in the two CTEs and the last phase took a total of three weeks to complete.

4.5. Instrument Development

The STAMPK framework described in Section 3.3 underpinned this study. The newly conceptualised framework for knowledge for technology integrated mathematics teaching was used in planning an appropriate PD program for mathematics teacher educators to use

technology in their teaching and in the design of instruments (questionnaires and an observation checklist). The interview questions and focus group discussion protocols were also designed in line with the research objective, research questions and the STAMPK framework.

4.5.1. Questionnaires and an observation checklist. Questionnaires were prepared and distributed to teacher educators and pre-service teachers before and after teacher educators participated in the PD program (see Section 4.4.1 for detail). The questionnaires were adapted from Schmidt et al. (2009) because these items formed the basis of the design of other instruments used in the study. The detailed procedure of the questionnaire development process for this study was reported in Getenet and Beswick (2013).

In diverse fields of study and a variety of contexts, instruments to measure teachers' knowledge of technology integrated teaching have been developed using the TPACK framework (e.g., Abbitt, 2011; Albion, Jamieson-Proctor, & Finger, 2010; Graham, Cox, & Velasquez, 2009; Koehler & Mishra, 2005; Schmidt et al., 2009). The current study, however, argued for the importance of understanding and explaining the use of the TPACK framework specific to mathematics teaching and the need for an instrument that could be used with mathematics teacher educators (see Chapter 3, Section 3.4). This led to the development of an instrument to measure mathematics teacher educators' STAMPK. The development process, detailed by Getenet and Beswick (2013), entailed conceptualising the TPACK framework for mathematics teaching, consideration of context, comparison with an existing instruments, expert review, and pilot testing. It drew on Colton and Covert's (2007) iterative process for instrument development, and the instrument development phases of Liang et al. (2008) to design the questionnaire. The process used is shown in Figure 4.2.

The first step was specifying the TPACK framework in relation to mathematics teaching (see Chapter 3 at Section 3.4 for details). This step supported the item design for each construct of STAMPK in terms of the new conceptualisation.

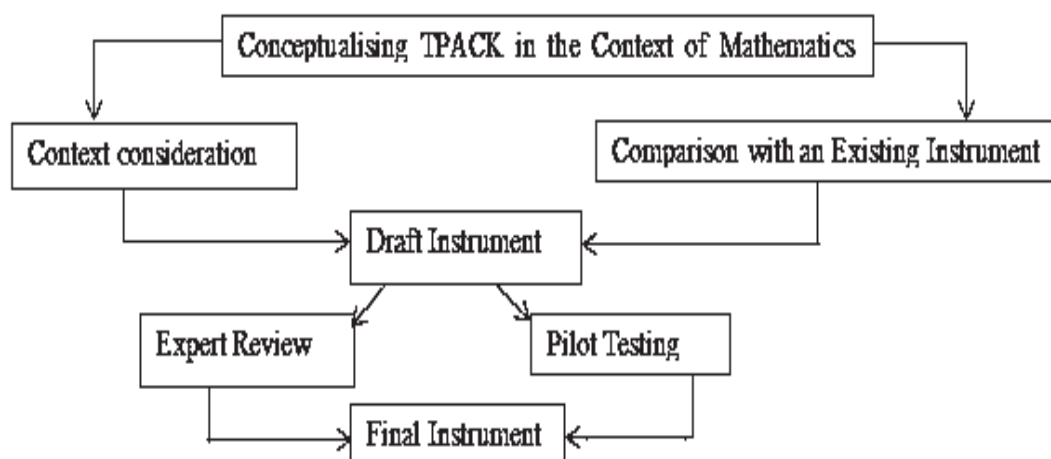


Figure 4. 2. Process of developing an instrument to measure mathematics teacher educators' STAMPK (Getenet & Beswick, 2013, p. 356).

The second step was considering the context. According to Colton and Covert (2007), the context in which an item is presented has an influence on the way respondents interpret and answer it. The items needed to be in relation to mathematics teacher educators in the context of College of Teacher Education (CTE) in Ethiopia. For example, there were items, which referred to how teacher educators can be models for their pre-service teachers in the use of technology in their teaching. Table 4.4 provides examples of items (item number) related to each of the STAMPK constructs.

Table 4. 4.

Examples of STAMPK Construct Items

STAMPK construct	Item number	Example
SMK	8	I have sufficient knowledge about mathematics
SPMK	20	I can select effective teaching approaches to guide pre-service teachers' thinking and learning in mathematics
STMK	26	I know about technologies that I can use to develop pre-service teachers' understanding of mathematics
STAMPK	40	I can provide leadership in helping others to teach ICT integrated mathematics with teaching approaches

Comparison with an existing instrument was the third step in developing the questionnaire. Similar to other studies (e.g., Agyei & Voogt, 2012; Chai, Koh, & Tsai, 2010; Koh, Chai, & Tsai, 2010), Schmidt et al.'s (2009) instrument was used as a frame but with redefinition of the TPACK framework from the perspective of teaching mathematics with technology, that is in relation to the STAMPK framework (Chapter 3 at Section 3.4). As described in Getenet and Beswick (2014), for example, the definition of CK in Mishra and Koehler's (2006) TPACK framework was reconceptualised to account for the distinctive nature of CK needed to teach mathematics, as described by Ball et al. (2008) and defined as "Specialised Mathematical Knowledge" (SMK). This specialised knowledge assisted in the design of items related to Content Knowledge (CK), later (SMK), of mathematics teachers in the TPACK framework. The definition for each of the newly conceptualised technologies integrated mathematics teaching components was compared with the items included in Schmidt et al. (2009). Based on the comparison, some items were revised, included or discarded based on the new conceptualisation

of TPACK, the context, and characteristics of participants in the study. Table 4.5 shows examples of how items related to TK were modified.

Table 4. 5

Modification of items for the Technological Knowledge (TK) construct of TPACK (Getenet & Beswick, 2013, p.358)

Schmidt et al. (2009) item	New items STAMPK	Justification
I know about technologies that I can use for understanding and doing mathematics.	<p>I can use a wide range of technologies to teach maths.</p> <p>I can select technologies to use in my classroom that enhance what I teach</p> <p>I can't think of teaching maths without the use of technology</p> <p>I know how to cement the knowledge needed to teach maths with the application of technologies</p>	<p>The item in Schmidt et al. (2009) was considered inadequate to measure teacher's TCK; hence there was a need to include more items. In addition, the special type of knowledge needed for mathematics teachers should be measured in relation to the application of technology not simply knowledge of it</p>

After conceptualising the definition of TPACK framework, considering the context, and comparing with an existing instrument, a draft instrument for measuring mathematics teacher educators' knowledge for technology integrated mathematics teaching was designed. In the draft questionnaire, 41 items were constructed requiring responses on five point Likert scales from Strongly Disagree to Strongly Agree. Open ended questions were added to invite participants to explain their experience in relation to each of the items. The draft questionnaire also asked respondents to provide information about their experience of teaching at CTE and school level,

their access to various technologies, and the frequency with which they used these technologies, and their confidence to undertake a range of tasks involving the use of technology. Following the design of the draft instrument, two experienced mathematics education professors, who were supervisors of this study, reviewed the questionnaire and several changes were made. Some of the changes included adaptations to address explicitly mathematics teacher educators' work, splitting 'double-barrelled' items and including additional open ended items (see Getenet & Beswick, 2013, pp. 359-360).

After the instrument was reviewed by two experienced mathematics education professors, a pilot test with a small group of mathematics teacher educators (five responses were obtained) was conducted. The pilot test assisted in addressing problems that might occur during administration. Furthermore, this step was essential in checking that the items were such that the instrument was likely to fulfil its purpose, and that it was unlikely that participants in the study would misunderstand (Colton & Covert, 2007). The pilot testing revealed that some items were vague and too broad. As a result, several items were modified. For example, one open ended question read, "In your opinion, what are the challenges in using technology into your teaching of pre-service teachers?" In relation to this item, one respondent commented "so many." This indicated that the question was too broad and hence, there was a need to modify the question to focus on a mathematics teaching. The final questionnaire contained the items in the revision provided in Appendix F.

An observation checklist was used to evaluate teacher educators' technology integrated mathematics teaching practices before and after participating in the refined PD program. The checklist was adapted from Agyei and Voogt (2011) and modified to evaluate mathematics

teacher educators' technology integrated teaching practices based on their STAMPK framework. The same two experienced mathematics education professors reviewed the observation checklist in terms of the new conceptualised STAMPK framework. The final observation checklist contained 20 items to measure each STAMPK construct and a space to explain the observed practices (see Appendix K). Table 4.6 shows examples of items of the observation checklist on each constructs of STAMPK.

Table 4. 6

Examples of Item of the Observation Checklist on each STAMPK Construct

STAMPK construct	Item number	Example The teacher educator...
SMK	1	Clearly introduced the topic and learning goals
SPK	5	Engages pre-service teachers in exploring real-world issues and solving authentic problems using teaching resources
TK	8	Demonstrates developed knowledge in selecting technology skills
SPMK	12	Applies teaching approaches which gives more authority to pre-service teachers in solving mathematics problem
STPK	14	Uses the technology used to help pre-service teachers to collaborate
STMK	15	Clearly link between technology and the specialised mathematics knowledge
STAMPK	18	Choose appropriate technology in relation to the mathematics concept and pedagogy

4.5.2. Interview and focus group discussion questions. The interview questions were prepared in relation to the research questions. As recommended by Diefenbach (2009), these questions were few in number, but allowed for in-depth probing of views and thoughts. The interview began with icebreaker questions, followed by a series of questions addressed

STAMPK, and then some general summary questions in line with Creswell's (2014) suggestion. Moreover, Legard, Keegan and Ward (2003) suggested three aspects to consider while formulating interview questions. The first is using a combination of broad and narrow questions. Wide questions were included to map the territory or dimension of an issue whereas narrow questions were needed for further probing. The second aspect was to avoid asking leading questions. Legard et al. (2003) suggested that leading questions do not allow participants to supply responses but influence the answers. The third aspect to consider was asking clear questions. According to Legard et al. (2003) clarity can be achieved through formulating interview questions that are short and leave the interviewee with no uncertainty about the kind of information sought. This includes avoiding double questions, avoiding questions that are too abstract or theoretical, and considering language and terminology sensitive to the participants. Considering the suggestions by Creswell (2014) about the order of interview questions and Legard et al's. (2003) recommendations about the techniques of formulating quality interview questions, interview questions were formulated for three different groups of the study participants: teacher educators, pre-service teachers and ICT coordinators. Interview questions for teacher educators consisted of 11 before and 15 items after teacher educators had participated in the PD program respectively. The interview questions for pre-service teachers numbered five both before and after teacher educators participated in the PD program. The interview questions for ICT coordinators consisted of seven questions both before and after the PD program (see all the interview questions at Appendix L). Table 4.7 shows examples of interview question for teacher educators, pre-service teachers and ICT coordinators before the PD program.

Table 4. 7

Examples of Interview Questions before the PD Program

Item	Teacher educator	Pre-service teacher	ICT coordinator
1	What importance do you place on technology in teaching pre-service teachers?	How important to you is learning with technology supported lessons?	What kind of support do you provide for teacher educators?
2	What do you think are the challenges to integrating ICT in teaching?	Do you have opportunities to play around with technology while learning mathematics?	What do you think are the factors influencing teacher educators to use technology in their teaching?
3	What can you say about the availability of technological tools at the college?	If yes, do you found this helpful? In what way?	What kind of professional development will help you to help teacher educators to use technology in their teaching?

The focus group discussion questions were formulated based on the recommendations of Gill et al. (2008) in order to generate information on the collective views of pre-service teachers and teacher educators, and the meanings that lay behind those views. Further, questions were formulated to probe participants' rich understanding, experiences and beliefs about technology integrated mathematics teaching. The discussions with teacher educators were conducted before (consisting of seven questions) and after (consisting of five questions) their participation in the refined PD program whereas the discussion with pre-service teachers was guided by five questions and was conducted after the teacher educators participated in the refined PD program. A discussion protocol was designed to assist their discussion to run smoothly and to follow up the discussion to the point objectives of the focus group discussion (Flick, 2009). The two

experienced mathematics education professors reviewed both interview and focus group discussion questions several times to test the clarity of initially designed questions as well as of the entire interview schedule. Table 4.8 shows examples of items used for focus group discussion with the teacher educators before the PD program and pre-service teachers after the PD program.

Table 4. 8

Examples of Focus Group Discussion Questions

Item	Teacher educators	Pre-service teachers
1	As teacher educator, what do you think are the key things that make a good classroom teacher?	What do you think of technology integrated lessons?
2	What importance do you place on technology in teaching mathematics?	Have you observed any difference in the habit of teacher educators' use of technology integration between before and after intervention activities? What differences?
3	What should be done in the future to enhance teacher educators' skills to integrate technology in their teaching?	Have you had a chance to play around with technologies these days?

4.6.Data Analysis

The data collected (quantitative and qualitative) were analysed using different approaches. The quantitative data including teacher educators' and their pre-service teachers' responses to the questionnaires, and the results of the observation checklist, were summarised using descriptive statistics. The qualitative data were analysed through thematic categories following the six steps suggested by Braun and Clarke (2006) and reported as recommended by Ryan and Bernard

(2003). The following two sub sections describe the quantitative and qualitative data analysis procedures.

4.6.1. Quantitative data analysis. The quantitative data were collected using questionnaires and an observation checklist. The data gathered were summarised using descriptive statistics as an initial step in making sense of particular data as suggested by Treiman (2009). Statistical data in this study included numerical data showing the strength of participants' responses to the questionnaire items and researcher rated observation data. Using SPSS software frequency tables, modes, means, standard deviations, Cohen's d and paired sample t -tests were used to analyse the data.

The Cohen's d effect size analysis was used to indicate the magnitude of the effect gained as the result of the PD program on teacher educators' STAMPK, comparing the practices of teacher educators' teaching before and after participating in the PD program. According to Cohen (1988), the effect is small when $d = 0.2$, medium when $d = 0.5$ and large effect when $d = 0.8$. Figures 4. 3 and 4.4 illustrates the quantitative data analysis procedure of the questionnaires and observation checklist data exemplified by the single subscale called Specialised Mathematics Knowledge (SMK).

The Specialised Mathematics Knowledge (SMK) subscale consisted of eight items in the questionnaire distributed to 16 teacher educators before and after the teacher educators participated in the PD program.

After finding the Mean (M) and Standard Deviation (SD) of this subscale, mean comparisons (paired sample t –tests) and Cohen's d was performed to compare teacher educators' SMK before and after they participated in the PD program.

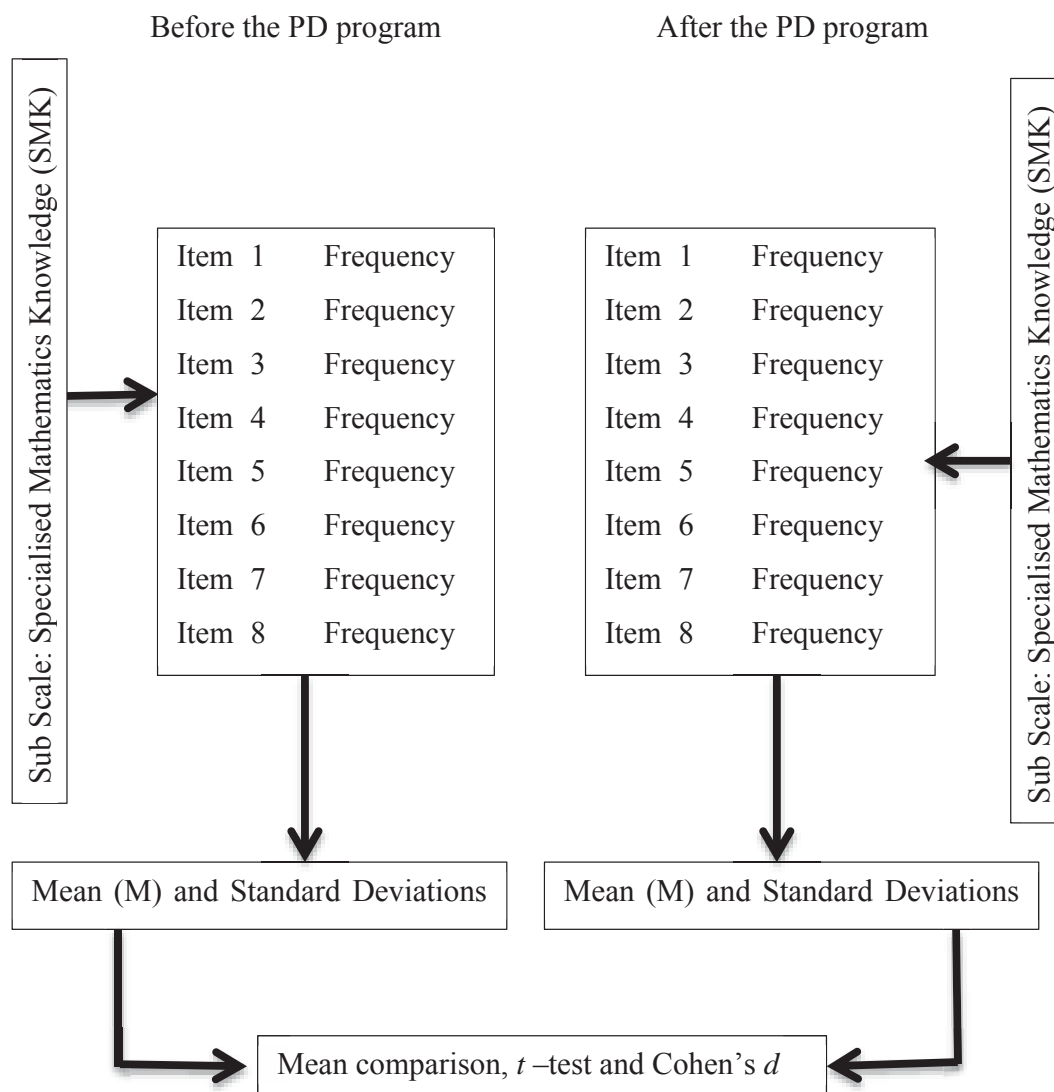


Figure 4. 3. Analysis procedure for questionnaire data for a single subscale.

The observation checklist was rated by watching video recorded lessons and making notes in the space provided in the observation checklist as recommended by Stigler and Hiebert (1997), emphasising those parts of the lesson relevant to the research questions. Consistent with the advice of Barron and Engle (2007), the analysis emphasised aspects of technology use known

to be relevant, such as how the pre-service teachers interacted with the mathematics software, specifically their use of the tools it provided, and how they worked to make sense of their learning. Two mathematics educators who were supervisors of the study and with experience in the analysis of observational data also reviewed the videos and verified the coding to the extent possible given that some of the lessons were not conducted in English.

The mode was used to compare the teacher educators' SMK before and after participating in the refined PD program as observed in the classroom based on three items, as summarised in Figure 4.4.

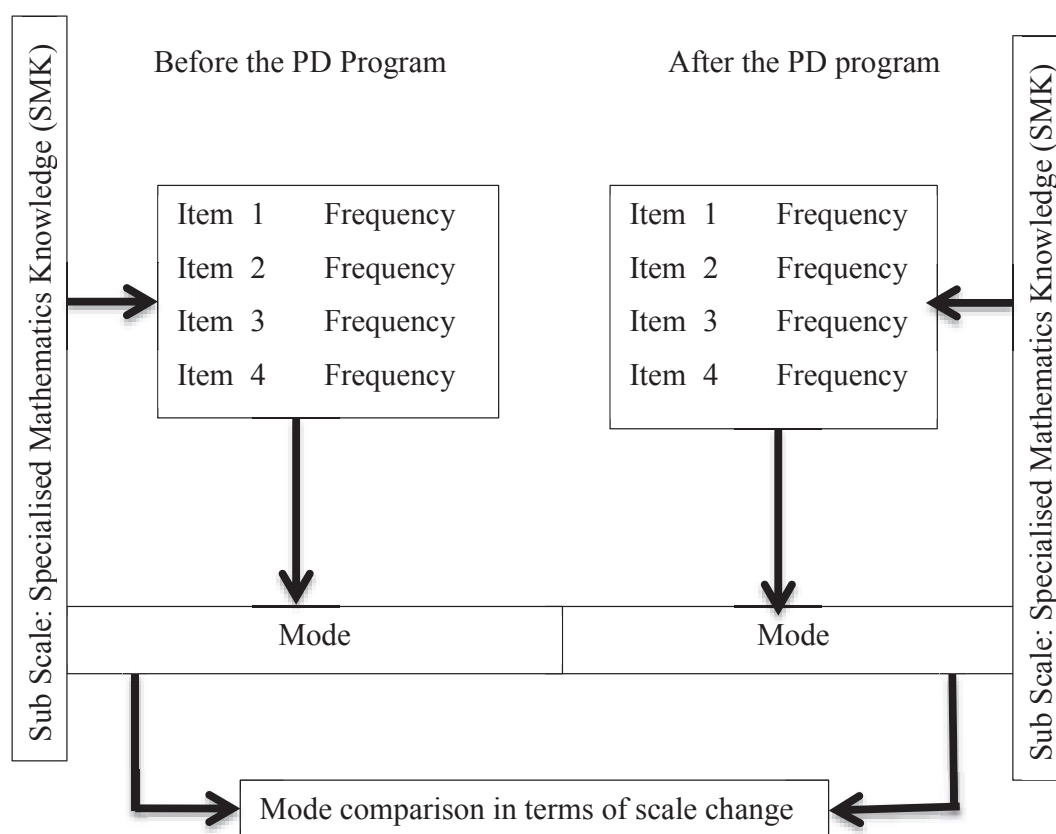


Figure 4. 4. Analysis procedure for observation data for a single subscale.

Because only six teacher educators were involved in the observation session and the scale used had only three points, the mode was used to better compare their practices before and after participating in the refined PD program from the observed data.

4.6.2. Qualitative data analysis. The qualitative data comprised interviews, focus group discussions, workshops and responses to open ended questions on the questionnaires, and notes recorded on observation checklists. These were analysed by thematically categorising into clusters that addressed the same issue. First, each set of data were transcribed and imported into Excel for filtering purpose and again transported to Microsoft Word to highlight the identified themes. The transcripts were read several times to obtain a sense of the whole. As suggested by Johnson and Christensen (2004) the qualitative data analysis used an inductive approach. Instead of stating hypotheses at the beginning, the researcher generated categories from the participants' responses (Creswell, 2009) as themes emerged. Ryan and Bernard (2003) detailed the potential sources of themes by defining themes as repetition ("repetition = theme" [p.89]). They suggested that themes were identified by searching through texts and marking them with different coloured pens. In keeping with the definition of themes as repetition, the following six steps were followed to analyse the qualitative data as suggested by Braun and Clarke (2006) and shown in Table 4.9.

A sample of qualitative data analysis is provided in Appendix M showing how the transcribed data were recorded in an Excel spreadsheet and how themes were identified on Excel sheets using the steps shown in Table 4.9. A consistent code name was given for each of the teacher educators, pre-service teachers, and ICT coordinators in the reporting of the qualitative data.

Table 4. 9

Phases of Thematic Analysis (Braun & Clarke, 2006, P. 87)

Phases	Description of the process
1. Familiarisation with the data	Data transcribed, reading and re-reading the data, noting down initial ideas
2. Generating initial codes	Interesting features of the data coded in a systematic fashion across the entire data set, collating data relevant to each code
3. Searching for themes	Codes collated into potential themes, gathering all data relevant to each potential theme
4. Reviewing themes	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic ‘map’ of the analysis
5. Defining and naming themes	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme
6. Producing the report	Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis

Finally, the qualitative data and the quantitative results were combined and triangulated to make a meaningful whole (Creswell, 2009) using a mixed methods approach as suggested by O’Cathain, Murphy, and Nicholl (2010). O’Cathain et al. indicated that a unique aspect mixed methods studies is the availability of both qualitative and quantitative data on the same cases. In this study, the data examined in detail for each case were combined; for example, comparing participants’ responses to a questionnaire with their interview transcript. At the later stage, the

complete data set was compared to and contrasted with the theoretical literature reviewed in Chapter 3.

4.7. Chapter Summary

This chapter provided an overview of how the study was carried out along with the justification of the approach, methodology, and tools used to carry out data collection and details of analysis. Detailed descriptions of the methods and tools have been given together with a rationale for using them in this study. One of the strengths of this study was the use of a mixed methods approach in order to provide multiple perspectives for understanding the complexity of technology integrated mathematics teaching and the design of the PD program to support teacher educators' technology integrated teaching practices. This chapter has also provided a connection between the theoretical background of the study as discussed in Chapter 3 and the process of designing the data collection instruments. In summary, this chapter has provided a detailed account of the design of the study, research, site selection, participant recruitment and sampling, research instrument design, and data analysis process of the overall study. The next chapter, Chapter 5, presents the results based on the data collected as described in this chapter. The chapter is divided into three major sections as per the design of the study, detailing the results of Phases 1, 2 and 3.

Chapter 5 Results

The previous chapter outlined the methodology used in the study. The current chapter, organised in three sub-sections, presents the results found based on the design process and data gathering techniques as described in Chapter 4. Section 5.1 describes the results of the context analysis. It documents teacher educators' technology integrated teaching practices before participation in the PD program and factors hindering their use of technologies in teaching. These results relate to Research Questions 1. Section 5.2 elaborates on the design of the PD program based on the context analyses identified in Section 5.1. It also discusses the data itself to show the process of formative evaluation and implementation of the revised PD program. It describes a PD program that supported teacher educators' effective technology integrated teaching. Results related to Research Questions 2 and 3 are provided in this section. Finally, Section 5.3 describes the impact of a PD program with regard to changes in the participant teacher educators' technology integrated teaching practices. It compares teacher educators' technology integrated teaching practices before and after their involvement in the revised PD program and presents findings related to the Research Question 4.

5.1. Context Analysis for the Design of a PD Program

The researcher considered the context and relevant literature in order to design the first PD program prototype, Prototype I. Two aspects guided the context analysis as explained in Chapter 3, Section 3.5.2. Firstly, an analysis of the learning context described in terms of the availability of technologies, the PD program practices of the Colleges of Teacher Education (CTEs), the kinds of the PD program required by teacher educators, and the CTEs mathematics department policy on the use of technology in teaching. The second involved an analysis of teacher

educators' and pre-service teachers' contexts. Teacher educators' contexts included their beliefs about the use of technology in teaching, their perceived proficiency in relation to using technology in their daily lives, their current Specialised Technological and Mathematics Pedagogical Knowledge (STAMPK), the value they ascribed to technology integrated teaching, and the types of PD programs they had attended previously. Pre-service teachers' context included their perceived proficiency in relation to using technology in their daily lives, beliefs in the use of technology in teaching, the value placed on learning through technology and factors influencing in the learning with technology in the context of the CTEs.

The researcher used the procedure shown in Figure 3.7 in Chapter 3, Section 3.6.4 to design the first PD program prototype. The initial context analysis was based on themes around the domains of context suggested by Smith and Ragan (2005), as shown in Table 4.1 in Chapter 4, Section 4.2.

The section following presents the findings based on the domains of the context analysis. The findings are the results found before teacher educators participated in the revised PD program that is from Phase 1 of the study.

5.1.1. Teacher educators' and pre-service teachers' context. In this section the teacher educators and pre-service teachers' demographic data, their perception on the use of technology in teaching, and their Technology Proficiency Self Assessment is presented. In addition, the teacher educators' perception on each construct of STAMPK is presented.

5.1.1.1. Teacher educators. Section 5.1.1.1 presents teacher educators' demographic data, beliefs about the use of technology, TPSA, perceived knowledge on each STAMPK construct and practices of classroom teaching. The findings were obtained from the first questionnaire, interview and classroom observations.

5.1.1.1.1. Demographic Data. Sixteen teacher educators were participants in the study during the context analysis phase. Of those, all the three female mathematics teacher educators were included. In Ethiopia, most mathematics teacher educators are male, with only a small number of female mathematics teacher educators. Hence, this sample is reasonably representative of the population of mathematics teacher educators in Ethiopia. Table 5.1 indicates the gender and age ranges of teacher educators.

Table 5. 1

Gender and Age Range of Teacher Educators

CTE	Gender		Age range			
	M	F	24 - 28	29 – 33	34 – 38	>38
College 1	5	2	2	2	2	1
College 2	8	1	0	2	2	5
Total	13	3	2	4	4	6

More than half of the teacher educator participants were over 33 years of age (N = 10). Most of the participant teacher educators had teaching experiences at both primary and secondary levels before joining a CTE as a teacher educator, half had teaching experience at primary school level (N = 8) and 11 had taught at a CTE for between 6 and 10 years. Table 5.2 summarises the teacher educators' experience at each of the three levels of schooling.

Table 5. 2

The Teacher Educators' Teaching Experiences

Years of teaching experience	Teaching experience					
	Primary school		Secondary School		CTE	
	N	%	N	%	N	%
0	8	50.0	2	8.0	-	-
1 - 5	5	31.3	7	53.2	4	25.0
6 - 10	2	12.5	4	26.7	11	68.8
11 - 15	1	6.2	0	0	0	-
>15	0	0	2	13.3	1	6.3
Total	16		15		16	

5.1.1.1.2. Beliefs about the use of technology in learning. Teacher educators were asked to indicate their agreement on the contribution of technology could make to the learning of mathematics on a continuum (from no contribution to learning to a very high contribution to learning). All of the participants indicated that technology can make a high contribution to learning (N = 9 [56.3%]) or very high contribution to learning (N = 7 [43.8%]). Table 5.3 shows the summary.

Table 5. 3

The Contribution of Technology to Learning as Rated by Teacher Educators

Item	N	%
Technology makes no contribution to learning	0	0
Technology makes little contribution to learning	0	0
Technology makes a high contribution to learning	9	56.3
Technology makes a very high contribution to learning	<u>7</u>	43.8

Total	16	100.0
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The positive perceptions towards the potential contribution of technology to mathematics learning encouraged the teacher educators to use it in their teaching.

5.1.1.1.3. Technology proficiency self assessment. The Technology Proficiency Self-Assessment (TPSA), adapted from Ropp (1997) as described in Chapter 4, Section 4.4.1.1 was used to identify teacher educators' perceived proficiency in relation to using technology in their daily lives. The results in Table 5.4 show the item Number (No.), the number of occurrences (N), Mean (M) and Standard Deviation (SD) of teacher educators' response to a five point Likert type items of the TPSA ordered from highest average agreement to the lowest. The overall mean of responses was $M = 3.72$ with $SD = 0.50$.

As shown in Table 5.4, teacher educators had means above 3, signifying overall agreement to 19 out of the 20 items except one teacher educator who did not complete these questions. The most strong agreements were with saving documents so that others can read them if they have different word processing programs (Item 15, $M = 4.47$, $SD = 0.52$) and keeping copies of outgoing messages sent to others (Item 5, $M = 4.14$, $SD = 0.36$). Although there is considerable variation in response patterns, teacher educators, were on average less positive in relation to their perceived proficiency in creating their own World Wide Web home page (Item 8, $M = 2.67$, $SD = 1.11$) and using specific mathematical software such as GeoGebra (Item 13, $M = 2.80$, $SD = 1.01$).

Table 5. 4

Teacher Educators' TPSA (N = 15)

Item No.	Item	N					M	SD
		1	2	3	4	5		
15	I feel confident that I could...	0	0	0	8	7	4.47	0.52
	Save documents in formats so that others can read them if they have different word processing programs (e.g., saving Word, ClarisWorks, RTF, or text)							
5	Keep copies of outgoing messages that I send to others	0	0	0	12	2	4.14	0.36
3	Create a "nickname" or an "alias" to send e-mail to several people at once	0	0	0	13	2	4.13	0.35
4	Send a document as an attachment to an e-mail message	0	0	0	13	2	4.13	0.35
7	Search for and find information in different Web sites	0	0	0	13	2	4.13	0.35
10	Find primary sources of information on the Internet that I can use in teaching	0	0	0	14	1	4.07	0.26
16	Use the computer to create a slideshow presentation	0	0	0	14	1	4.07	0.26
18	Create a lesson or unit that incorporates subject matter software as an integral	0	0	0	14	1	4.07	0.26
6	Use an Internet search engine (e.g., Google, wiki etc.) to find Web pages related to mathematical concepts	1	0	0	12	2	4.00	0.65
9	Keep track of Web sites I have visited so that I can return to them later	0	0	0	14	1	4.00	0.00
1	Send an email to a friend	0	1	0	12	2	4.00	0.65
2	Subscribe to a discussion list	0	1	0	13	1	3.93	0.59
21	Write a plan with a budget to buy technology for my classroom	0	0	0	1	14	3.93	0.26
11	Use a Spreadsheet in teaching mathematics like geometry	0	2	1	11	1	3.73	0.80
19	Use technology to collaborate with other interns, teacher educators, or pre-service teachers who are distant from my classroom	0	0	9	6	0	3.40	0.50
14	Use multiple mathematical software in teaching mathematical concept	0	0	5	1	9	3.27	0.96
17	Create a database of information about important authors in a subject	0	6	1	8	0	3.13	0.99
20	Describe different software programs that I would use in my teaching	0	0	3	7	5	3.13	0.74
12	Use Microsoft mathematics in teaching mathematics like quadratic equation	0	7	0	8	0	3.07	1.03
13	Use GeoGebra in teaching mathematics like geometry	1	7	1	6	0	2.80	1.08
8	Create my own World Wide Web home page	2	6	2	5	0	2.67	1.11

1 = Strongly Disagree (SD), 2 = Disagree (D), 3 = Undecided (UD), 4 = Agree (A), 5 = Strongly Agree (SA)

In addition, teacher educators were asked to indicate the extent of their agreement with items related to each construct comprising STAMPK. Responses to these items were also provided on five point Likert scales (1 = Strongly Disagree to 5 = Strongly Agree). Tables 5.5 to 5.11 shows the number of teacher educators who responded to a particular item (N), Mean (M) and Standard Deviations (SD) of teacher educators' personal beliefs on each item of the STAMPK construct. In each of Tables 5.5 to 5.11 (N = 16), the items are ordered from highest to lowest mean.

5.1.1.1.4. Teacher educators' Technology Knowledge (TK). The overall mean response in Table 5.5 shows that teacher educators were neutral about their TK (Overall M = 3.04, SD = 1.08).

Table 5. 5

Teacher Educators' TK before Participating in the PD Program

No.	Item	N					M	SD
		1	2	3	4	5		
7	I have had sufficient opportunities to work with different technologies	0	0	1	8	7	4.38	0.62
2	I can learn technology easily	0	1	1	13	1	3.88	0.62
3	I keep up with important new technologies	0	6	2	8	0	3.13	0.96
1	I know how to solve my own technical problems	0	6	4	6	0	3.00	0.89
6	I have the technical skills I need to use technologies	1	10	1	4	0	2.50	0.97
4	I frequently play with technologies	0	14	0	2	0	2.25	0.68
5	I know about many different technologies	2	9	4	1	0	2.25	0.77
	Overall mean response						3.04	1.08

The standard deviation (SD = 1.08), shows that the responses were spread out over a large range of values. Although teacher educators agreed that they had sufficient opportunities to work

with different technologies (Item 7, $M = 4.38$, $SD = 0.62$) and could learn technologies easily (Item 2, $M = 3.88$, $SD = 0.62$), they did not frequently play with technologies (Item 4, $M = 2.25$, $SD = 0.68$).

5.1.1.1.5. Specialised Mathematics Knowledge (SMK). Table 5.6 shows teacher educators' had high level of agreement with having SMK (Overall $M = 3.90$, $SD = 0.61$).

Table 5. 6

Teacher Educators' SMK before Participating in the PD Program

No	Item	N					M	SD
		1	2	3	4	5		
8	I have sufficient knowledge about mathematics.	0	0	0	12	4	4.25	0.45
9	I can use a mathematical way of thinking.	0	0	0	14	2	4.13	0.34
10	I have various ways of developing my understanding of mathematics.	0	1	1	13	1	3.87	0.62
12	I understand the difference between the knowledge required for teaching mathematics and common knowledge in mathematics.	0	1	3	12	0	3.69	0.60
11	I have a mathematical knowledge unique to teaching.	0	2	3	11	0	3.56	0.73
	Overall mean response						3.90	0.61

For example, they strongly agreed that they had sufficient knowledge about mathematics (Item 8, $M = 4.25$, $SD = 0.45$) and mathematical knowledge unique to teaching mathematics (Item 11, $M = 3.56$, $SD = 0.73$). Overall, they were very positive about their SMK across all items.

5.1.1.1.6. Specialised Pedagogical Knowledge (SPK). With regard to SPK, the teacher educators generally agreed that they had SPK with an overall mean (overall $M = 3.72$, $SD = 0.56$) as shown in Table 5.7.

Overall, the teacher educators strongly agreed that they had the knowledge to manage a classroom (Item 19, $M = 4.00$, $SD = 0.00$) could assess pre-service teachers' performance (Item 13, $M = 3.94$, $SD = 0.57$), and adapt these different teaching styles to different learners (Item 15, $M = 3.81$, $SD = 0.54$). In addition, the teacher educators agreed but less strongly that they were familiar with pre-service teachers' common misconceptions (Item 18, $M = 3.50$, $SD = 0.97$).

Table 5. 7

Teacher Educators' SPK before Participating in the PD Program

No	Item	N					M	SD
		1	2	3	4	5		
19	I know how to manage a classroom.	0	0	0	16	0	4.00	0.00
13	I know how to assess pre-service teachers' performance in a classroom.	0	1	0	14	1	3.94	0.57
15	I can adapt my teaching style to different learners.	0	1	1	14	0	3.81	0.54
16	I can assess pre-service teachers' learning in multiple ways.	0	2	1	12	1	3.75	0.77
17	I can use a wide range of teaching approaches in a classroom setting.	0	3	0	12	1	3.69	0.87
14	I can adapt my teaching based upon what pre-service teachers currently understand.	0	2	2	11	0	3.60	0.74
18	I am familiar with pre-service teachers' common misconceptions.	1	2	1	12	0	3.50	0.97
Overall mean response							3.75	0.71

5.1.1.1.7. Specialised Pedagogical Mathematics Knowledge (SPMK). Parallel to their SPK, Table 5.8 shows that on average the teacher educators agreed that they had knowledge of all the items under SPMK (overall $M = 3.72$, $SD = 0.56$).

They agreed on having, for example, the knowledge to select effective teaching approaches (Item 20, $M = 3.93$, $SD = 0.25$), and to anticipate mathematical concepts that pre-service teachers would find confusing (Item 24, $M = 3.63$, $SD = 0.62$).

Table 5. 8

Teacher Educators' SPMK before Participating in the PD Program

No.	Item	N					M	SD
		1	2	3	4	5		
20	I can select effective teaching approaches to guide pre-service teachers' thinking and learning in mathematics	0	0	1	15	0	3.93	0.25
22	I can solve pre-service teachers' mathematical misconceptions using appropriate pedagogy/teaching.	0	2	0	14	0	3.75	0.68
21	I can use a wide range of teaching approaches to teach mathematics	0	1	3	12	0	3.69	0.60
25	I can prevent pre-service teachers learning difficulties with appropriate teaching method	0	1	3	12	0	3.69	0.60
23	I can anticipate what pre-service teachers are likely to think and choose appropriate teaching approaches	0	0	6	10	0	3.63	0.50
24	I can anticipate mathematical concepts that pre-service teachers will find confusing.	0	1	4	11	0	3.63	0.62
	Overall mean response						3.72	0.56

5.1.1.1.8. Specialised Technological Mathematical Knowledge (STMK). In contrast to teacher educators' agreement with all items of SPK and SPMK, there was less agreement that they had aspects of STMK (overall $M = 2.14$, $SD = 0.71$) is shown in Table 5.9. Particularly, they were inclined to disagree with having the knowledge to use a wide range of technologies to teach mathematics (Item 27, $M = 1.56$, $SD = 0.63$), and to select technologies that enhanced their teaching (Item 28, $M = 1.81$, $SD = 0.83$).

Table 5. 9

Teacher Educators' STMK before Participating in the PD Program

No.	Item	N					M	SD
		1	2	3	4	5		
26	I know about technologies that I can use to develop pre-service teachers' understanding of mathematics	2	9	4	1	0	2.25	0.77
30	I know how to cement the knowledge needed to teach mathematics with the application of technologies.	3	11	1	1	0	2.00	0.73
29	I cannot think of teaching mathematics without the use of technology	6	7	2	1	0	1.88	0.88
28	I can select technologies to use in my classroom that enhance what I teach	6	8	1	1	0	1.81	0.83
27	I can use a wide range of technologies to teach mathematics	8	7	1	0	0	1.56	0.63
	Overall mean response						2.14	0.71

5.1.1.1.9. Specialised Technological Pedagogical Knowledge (STPK). From the overall mean ($M = 1.90$, $SD = 0.79$) in Table 5.10, it is evident that teacher educators on average disagreed that they had the knowledge of all aspects of STPK reflected in these items.

For example, they disagreed with having the knowledge to choose technologies that enhance pre-service teachers' learning for a lesson (Item 31, $M = 2.31$, $SD = 0.60$) and select technologies that enhance how they teach (Item 36, $M = 2.06$, $SD = 0.57$).

Table 5. 10

Teacher Educators' STPK before Participating in the PD Program

No.	Item	N					M	SD
		1	2	3	4	5		
31	I can choose technologies that enhance the teaching approaches for a lesson	0	12	1	3	0	2.43	0.81
32	I can choose technologies that enhance pre-service teachers' learning for a lesson	0	12	3	1	0	2.31	0.60
35	I can adapt the use of the technologies to different teaching activities	3	10	1	2	0	2.12	0.88
36	I can select technologies that enhance how I teach	2	11	3	0	0	2.06	0.57
33	Teaching pre-service teachers has caused me to think more deeply about how technology could influence the teaching approaches I use	2	13	1	0	0	1.93	0.44
34	I think critically about how to use technology in my classroom	4	10	1	1	0	1.93	0.77
	Overall mean response						1.90	0.79

5.1.1.1.10. Specialised Technological and Mathematics Pedagogical

Knowledge (STAMPK). The STAMPK construct reflects teacher educators' perceived knowledge about using technology to teach mathematics. In this regard, the overall mean ($M = 2.08$, $SD = 0.74$) in Table 5.11 shows that teacher educators on average did not believe they had the composite knowledge indicated by items addressing STAMPK, such as having the knowledge to teach lessons that appropriately combine mathematics content, technologies and teaching approaches (Item 33, $M = 2.19$, $SD = 0.75$). The teacher educators were least positive particularly in providing leadership role to support their colleagues to teach technology integrated mathematics with various teaching approaches.

Table 5. 11

Teacher Educators' STAMPK before Participating in the PD Program

No.	Item	N					M	SD
		1	2	3	4	5		
37	I can teach lessons that appropriately combine mathematics content, technologies and teaching approaches	2	10	3	1	0	2.19	0.75
38	I can choose technology to use in my classroom that enhances what I teach, how I teach and what pre-service teachers can learn	2	11	1	2	0	2.19	0.83
39	I can use strategies that combine mathematics content, technologies and teaching approaches.	2	10	3	1	0	2.19	0.75
41	I can understand pre-service teachers' misconceptions about mathematics concepts and can solve the misconceptions through the application of technology, which fit with a selected pedagogy	4	10	1	1	0	1.94	0.77
40	I can provide leadership in helping others to teach ICT integrated mathematics with teaching approaches	4	10	2	0	0	1.87	0.62
	Overall mean response						2.08	0.74

The summary of teacher educators' responses on each STAMPK item component based on the overall mean responses is shown in Table 5.12.

Table 5. 12

Summary of Teacher Educators' STAMPK

STAMPK Components	M	SD	Number of Items	Cronbach's Alpha
TK	3.04	1.08	7	0.77
SMK	3.90	0.61	5	0.75
SPK	3.75	0.71	7	0.78
SPMK	3.72	0.56	6	0.73
STPK	1.90	0.79	6	0.85
STMK	2.14	0.71	5	0.84
STAMPK	2.08	0.74	5	0.93

1 = Strongly Disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly Agree

Overall, the STAMPK questionnaire responses indicated that teacher educators were less inclined to think they had TK, STPK, and STAMPK, but indicated overall strong agreement with most of the items related to SMK ($M = 3.90$, $SD = 0.61$), SPK ($M = 3.75$, $SD = 0.71$) and SPMK ($M = 3.72$, $SD = 0.56$). Cronbach's Alpha result in Table 5.12 also indicates high overall internal consistency among the items of each STAMPK's construct.

In addition to the questionnaire, six teacher educators were asked in the interviews, prior to the PD, "What do you think are the things that a teacher educator needs to know?" In response, most of them mentioned that pedagogical and content knowledge are critical for teaching, but three also mentioned technology knowledge as a means for effective teaching. As illustrated in Chapter 4, Section 4.6.2, the interviews and focus group discussions were designed in English but participants had the opportunity to express their ideas with a mix of English and the local language (Amharic). For the purpose of this research, however, the English translation is reported. Typical responses acknowledged the importance of both content and pedagogical knowledge with technology sometimes mentioned to this question. Examples included:

I believe that an effective teacher educator should have content and pedagogical knowledge. That is why every teacher educator should attend Higher Diploma Program on which its focus is on Pedagogical Content knowledge. In the current days, technology knowledge could be also important. [Teacher Educator 2].

A teacher educator should be competent in his subject knowledge and later with pedagogy knowledge. I personally believe that content knowledge is vital to be an effective teacher educator. Even though, technology knowledge is important to be an effective teacher educator, I hardly used it in my teaching. [Teacher Educator 3].

Subject knowledge and constructivist approach of teaching are critical for an effective teacher educator. Technological knowledge is also important to facilitate the constructivist approach of teaching. [Teacher Educator 4].

None of the teacher educators mentioned technological knowledge in terms of its role in facilitating pedagogy and content.

5.1.1.1.11. Classroom observations. Teacher educators were observed while teaching technology integrated lessons before participating in the revised PD program. Two for each six teacher educators in total 12 lessons were observed and audited using the observation checklist described in Chapter 4, Section 4.4.1.3. Each lesson lasted at least 50 minutes. The results for all 12 lessons are shown Table 5.13, which shows the number of not observed, partly observed or observed practices in each lesson (N), the Mode and the description of observed practices of each construct of STAMPK. Of the observed lessons, 10 used overhead projectors as a technology with animated pictures. One teacher educator used SPSS to teach statistics and another teacher educator used Microsoft Excel to teach the concept of statistics.

Table 5. 13

Teacher Educators' Technology Integrated Teaching Practices as Audited Using an Observation Checklist before Participating in the

PD Program

STAMPK Constructs	N			Mode	Observed Practices	
	1	2	3			
Specialised Mathematics Knowledge (SMK)						
1	Clearly introduced the topic and learning goals	0	0	12	3	All teacher educators had a strong grasp of relevant mathematical content and organised this for effective teaching
2	Sufficient knowledge of the lesson	0	0	12	3	
3	Demonstrates confident in subject's concepts related to lesson	0	0	12	3	
4	Uses appropriate materials in relation to the given lesson being taught	0	11	1	2	
Specialised Pedagogical Knowledge (SPK)						
5	Engage pre-service teachers in exploring real-world issues and solving authentic problems using teaching resources	2	8	2	2	Most teacher educators predominately used the lecture method
6	Address the diverse needs of all learners by using learner centred strategies	8	4	0	1	
7	Provide equitable access to appropriate resources	10	0	2	1	
Technological Knowledge (TK)						
8	Demonstrates developed knowledge in selecting technology skills	2	8	2	2	Most teacher educators used the overhead projector as a replacement of chalk and board
9	Demonstrate fluency in the transfer of the used technology knowledge to new situations	8	2	2	1	
10	Demonstrate knowledge on effective combination of learning support tools	4	8	0	2	

Specialised Pedagogical Mathematics Knowledge (SPMK)						
11	Possess the ability to integrate teaching approaches that arouse pre-service teachers' creativity	4	6	2	2	Few teacher educators were observed using pedagogy that promoted the content to be delivered. In most cases, the method was used to transmit the message
12	Apply teaching approaches which gives more authority to pre-service teachers in solving the subject problem	8	2	2	1	
Specialised Technological Pedagogical Knowledge (STPK)						
13	Engage pre-service teachers in the pedagogy used in learning activities	4	6	2	2	The technology selected did not support the pedagogy in most cases
14	Use the technology used to help pre-service teachers to collaborate	10	0	2	1	
Specialised Technological Mathematics Knowledge (STMK)						
15	Clear link between technology and the specialised mathematics knowledge	6	2	4	1	The technology was used as a means to deliver the content rather than supporting learners to learn
16	Design relevant learning experiences that incorporate the technology used to promote pre-service teachers learning	8	0	4	1	
17	Introduction of fundamental concepts by technology incorporation	4	4	4	-	
Specialised Technological And Mathematics Pedagogical Knowledge (STAMPK)						
18	Proper choice of technology in relation to mathematics concept and pedagogy	10	0	2	1	Teacher educators were not observed selecting appropriate technology which facilitated the delivery of a particular content fitted with the lecture method
19	Clearly integrate the components of STAMP to promote creative thinking in pre-service teachers	10	2	0	1	
20	Apply STAMP to promote pre-service teachers' reflection and to clarify pre-service teachers' conceptual thinking.	10	2	0	1	

1 = not observed, 2 = partly observed, 3 = observed

As shown in Table 5.13, teacher educators were observed partly using technology in their teaching to engage learners in many of the lessons. For example, most teacher educators used a PowerPoint presentation in their teaching.

Among the 12 lessons, the following lesson was selected because of the teacher educators' improved practices after their participation in the PD program to provide an example of the 12 lessons summarised in Table 5.13.

In the lesson observed a teacher educator used a PowerPoint presentation to teach the concept of increasing and decreasing functions. He used an overhead projector during the entire lesson to display written notes and the graphs of increasing and decreasing functions. The PowerPoint presentation had some animated components, showing the graph either increasing or decreasing as the values of x and y was varied. The following section describes the lesson as it unfolded in the classroom.

First, the teacher educator displayed the definition of decreasing and increasing functions respectively as:

Definition of Increasing and Decreasing functions

A function is *increasing* on an interval if for any x_1 and x_2 in the interval then

$$x_1 < x_2 \quad \text{implies} \quad f(x_1) < f(x_2)$$

A function is *decreasing* on an interval if for any x_1 and x_2 in the interval then

$$x_1 < x_2 \quad \text{implies} \quad f(x_1) > f(x_2)$$

Later, the teacher educator showed animated graphs of decreasing and increasing functions on a screen with generalised formulas as indicated in Figure 5.1.

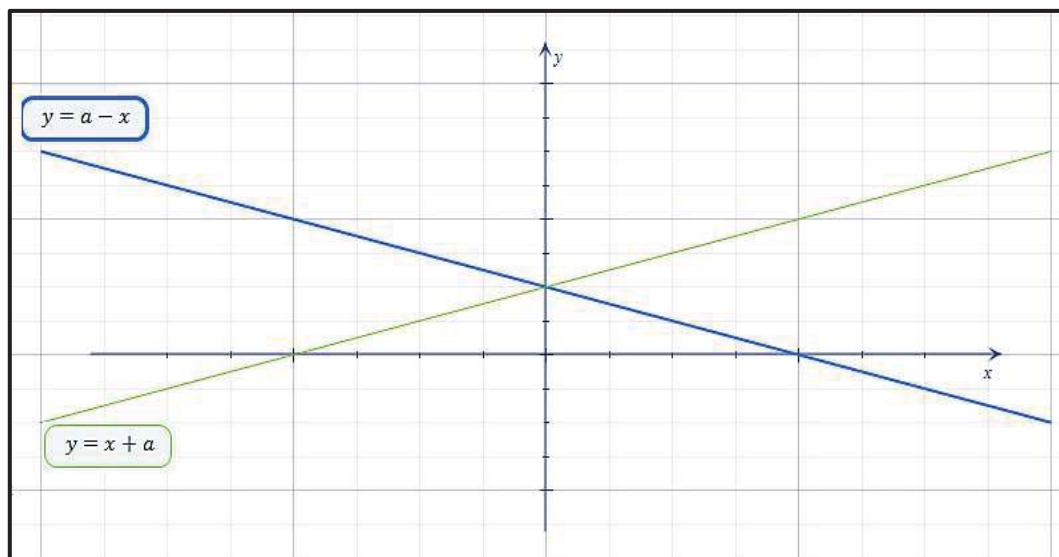


Figure 5. 1. Graph of a decreasing and an increasing function.

The observation results showed that this particular lesson partly engaged pre-service teachers who appeared interested in the animated part of the PowerPoint presentation. The completed audit of this lesson is provided in Appendix P.

The most frequently observed practices in relation to each item for each construct of STAMPK during this lesson (mode values) are shown in Table 5.14 followed by a description of the observed practices. As shown in Table 5.14, the teacher educator was not observed using the technology to support pedagogy for the development of students' understanding (STPK). Nevertheless the teacher educator chose technology application that fitted with the special type of mathematics knowledge (STMK) (Mode = 3).

Table 5. 14

STAMPK Results as Rated Using the Observation Checklist

STAMPK Components	Mode	Description of observed practices
TK	2	The teacher educator used PowerPoint efficiently. No technical problem was observed using the PowerPoint. Pre-service teacher did not use any technology
SMK	3	The teacher educator had sufficient knowledge on the topic
SPK	2	The teacher educator lectured using an overhead projector as a replacement for a board
SPMK	1	A range of pedagogical approaches with the topic, and involving pre-service teachers was not observed, which fitted with the content
STPK	1	The technology selected did not seem to fit with the lecture method. Learners were passive but partly engaged watching the animated graph
STMK	3	There was a clear link between pedagogy and content. The animation was engaging and thought provoking
STAMPK	1	The technology, pedagogy and the mathematics content did not work in harmony during the lesson to facilitate learning

1 = not observed, 2 = partly observed, 3 = observed

5.1.1.1.12. Type of PD programs attended. As part of the questionnaire, teacher educators were asked to list the types of PD programs they had attended to support the integration of technology in their teaching. The results in Table 5.15 shows the foci of PD programs attended by teacher educators categorised by general technology skill, including basic computer skills, pedagogical use of technology, and other. The other category included PD programs on SPSS (used for non-teaching purposes), and software used for administrative purposes. The majority of teacher educators' had attended PD programs related to general

technology skills (N = 10 [62.5%]). PD programs listed by the teacher educators under general technology skill included programs that addressed basic computer skills and use of the internet. Only one participant indicated that he had attended a PD program about the pedagogical use of technology.

Table 5. 15

PD Program Foci Attended by Teacher Educators

PD program foci	N	%
General technology skill	10	62.5
Pedagogical use of technology	1	6.25
Other	5	31.25

5.1.1.2.Pre-service teachers' context

This section presents the pre-service teachers' contexts in terms of their demographic data, beliefs about the use of technology in learning and responses to the TPSA.

5.1.1.2.1. Demographic data. One hundred and twenty 1st and 2nd year elementary pre-service teachers participated in the study. Table 5.16 shows the numbers of pre-service teachers in each year level, gender and whether or not they had teaching experience.

Table 5. 16

Pre-Service Teachers' Age Range, Gender and Teaching Experience

CTE	Year level		Gender		Teaching experience	
	1 st	2 nd	M	F	Yes	No
College 1	31	26	27	30	2	55
College 2	32	31	28	35	4	59
Total	63	57	55	65	6	114

It shows that of the 120 participants who completed the first questionnaire, most had no teaching experience (N = 114). The number of female (N = 65) participants was slightly higher than the number of males (N = 55).

5.1.1.2.2. Beliefs about the use of technology in learning. Pre-service teacher participants were asked to indicate the strength of their beliefs about the importance of technology in learning on a continuum from ‘no contribution to learning’ to ‘very high contribution for learning’. Table 5.17 shows that a high number of participants (N = 106, 87.6%) except who did not answer this item (N = 3) believed technology could make a high or very high contribution to learning.

Table 5. 17

Importance of Technology in Learning Rated by Pre-Service Teachers

Items	N	Percent
Technology makes no contribution to learning	1	0.8
Technology makes little contribution to learning	10	8.3
Technology makes a high contribution to learning	43	35.5
Technology makes a very high contribution to learning	63	52.1
Total	117	96.7

Furthermore, during the interviews the pre-service teachers were asked how much they valued learning with technology. Most pre-service teachers valued technology integrated teaching for its capacity to facilitate understanding and engage learners. Pre-service Teacher 5 gave the following illustrative response:

I believe learning with technology has dual advantages for us as pre-service teachers and learners. It could increase our engagement in the lesson while learning, and develop our

experience and the skill to integrate technology in our own future teaching. [Pre-service Teacher 5].

5.1.1.2.3. Pre-service teachers' TPSA. The questionnaire administered to pre-service teachers included a subset of the items in the section that used to identify teacher educators' TPSA. The pre-service teachers indicated frequently their agreement (overall $M = 3.58$, $SD = 0.35$) at being proficient with technology on most of the TPSA items. The results shown in Table 5.18 shows the item Number (No.), Frequencies (N), Mean (M) and Standard Deviation (SD) of pre-service teachers' responses on a five point Likert type scale to the items of TPSA ordered from highest average agreement to lowest.

Table 5.18 shows that pre-service teachers tended to agree with most of the TPSA items (Overall $M = 3.57$, $SD = 0.17$) ordered from highest to lowest mean except those who did not respond to some of the items. There were some items, however, which on average the pre-service teachers' agreed more strongly. These items were related to subscribing to a discussion list (Item 2, $M = 2.74$, $SD = 1.43$) and creating one's own World Wide Web home page (Item 8, $M = 3.32$, $SD = 1.29$).

Table 5. 18

Pre-Service Teachers' TPSA

Item No.	Item	N					M		SD
	I feel confident that I could...	1	2	3	4	5			
15	Save documents in formats so that others can read them if they have different word processing programs (e.g., saving Word, ClarisWorks, RTF, or text)	2	8	7	75	27	3.98	0.84	
7	Search for and find information in different Web sites.	0	2	12	90	13	3.97	0.53	
3	Create a "nickname" or an "alias" to send e-mail to several people at once.		2	3	12	84	3.92	0.7	
1	Send an e-mail to a friend.	3	9	8	84	14	3.82	0.83	
10	Find primary sources of information on the Internet that I can use in teaching mathematics	2	11	14	71	21	3.82	0.89	
11	Use a Spreadsheet in teaching mathematics like geometry	11	19	10	51	27	3.8	3.08	
9	Keep track of Web sites I have visited so that I can return to them later. (An example is using bookmarks).	4	10	13	74	17	3.76	0.92	
16	Use computer and software for different purposes like prepare slides, write assignments etc.	6	12	22	52	28	3.7	1.09	
4	Send a document as an attachment to an e-mail message.	3	17	5	82	11	3.69	0.92	
13	Use technologies which can help me to learn mathematics						3.52	1.29	
12	Use technologies which can help to learn quadratics equation	11	16	3	39	19	3.44	1.35	
14	Use multiple mathematical software in learning mathematical concept	15	22	9	47	26	3.40	1.35	
8	Create my own World Wide Web home page	16	18	15	50	19	3.32	1.29	
5	Keep copies of outgoing messages that I send to others	22	22	10	42	19	3.19	1.58	
6	Use an Internet search engine (e.g., Google, wiki etc.) to find Web pages related to mathematical concepts	20	16	19	50	14	3.19	1.3	
2	Subscribe to a discussion list	36	21	7	44	9	2.74	1.43	

1 = Strongly Disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly Agree

Further to TPSA item, during the interview, pre-service teachers were asked the question, “Do you have opportunities to play around with technology while learning mathematics?” All of the interviewees indicated that they did not have the opportunities to play around with technology for learning mathematics concepts. Some of the illustrative comments were:

I wish if I were able to learn mathematics using technology on my own pace. This was, however, not happened in the previous lessons. [Pre-service Teacher 3].

I had the opportunity to practice technology integrated learning while learning the concept of basic statistics like mean, standard deviation etc. [Pre-service Teacher 4].

I have attended my secondary school via plasma technology. I had not, however, an opportunity to practice with my own pace like touching and manipulating it. [Pre-service Teacher 2].

The interview results showed that pre-service teachers were interested in learning with technology, but believed that they did not have the opportunity to do so.

5.1.2. Analysis of the learning context. This section presents the results related to the PD need assessment and description of the learning environment. The need assessment further described, based on challenges in using technology by both teacher educators and pre-service teachers, and types of PD programs teacher educators would like to attend. The description of the environment was centred on the availability of technologies, and the CTEs’ policies on the use of technology in teaching.

5.1.2.1. Needs assessment.

5.1.2.1.1. Challenges in using technology identified by teacher educators and pre-service teachers. Teacher educators were asked in the questionnaire to list the challenges that

influenced their use of technologies in their teaching. The factors they identified were grouped into five categorical themes as described in Section 4.6.2 of Chapter 4 with an illustrative example provided in Appendix M. Table 5.19 shows the themes, the number of the teacher educators mentioned the theme, and summaries of each theme.

Table 5. 19

Factors that hinder the Use of Technologies in Teaching

Themes	N	Summaries
Lack of PD programs on pedagogical use of technology	13	How pedagogy is supported by technology
Lack of the required knowledge	9	Nine of them mentioned that they didn't have the required knowledge to use technology in teaching
Lack of experience and awareness	7	Seven mentioned having no awareness or experience of how to use technology in teaching
Lack of technology resources	5	No software
Others	2	Time constraints

As Table 5.19 shows, the most frequently mentioned challenges identified by teacher educators were lack of experience and awareness of using technology in teaching (N = 7), and lack of PD programs on pedagogical use of technology (N = 13).

During the teacher educators' interviews, lack of experience and awareness was also the most frequently mentioned factor that influenced the use of technology use in their teaching. For example, Teacher Educator 1 said:

To be honest, I have never experienced using technology in my previous lessons. In addition, I am not sure how to use technologies in my teaching. [Teacher Educator 1].

Teacher Educator 4 also identified lack of experience and awareness as factor influencing his technology integrated mathematics teaching:

I have never considered using technology in my teaching due to limited previous practices and the existence of established methods of teaching. However, I believe using technology in teaching facilitates learning and understanding. [Teacher Educator 4].

Absence of PD programs that focused on the pedagogical use of technology was another theme that emerged during the interviews as influencing teacher educators' technology integrated teaching. The following reflection by Teacher Educator 3 illustrates this:

The kind of PD programs organised in the CTE were emphasised on basic skill acquisitions like Microsoft Excel, SPSS. I prefer to attend different PD programs emphasising on how to use technology in teaching. [Teacher Educator 3].

Pre-service teachers were also asked in the questionnaire about the challenges to using technology but in terms of 'learning mathematics?' The responses from the pre-service teachers were themed according to the factors shown in Table 5.20. These factors were arrived at using the process described in Appendix M. Table 5.20 shows the themes, the number of pre-service teachers who mentioned each theme (N), and examples of responses.

Table 5. 20

Factors Influencing Pre-Service Teachers Learning with Technology

Themes	N	Examples of responses
Teacher educator teaching practices	60	I did not see the point of using technology in learning while teacher educators are not using it
Lack of motivation	17	We often liked to learn with traditional method of teaching, as it is the method often used. Hence, prefer to continue with the dominant method as I was not motivated to use technology as an alternative approach to facilitate learning
Limited technical support	15	No support from the department to use technology in our learning
Lack of awareness	15	I was not aware that the technology could be used in learning mathematics. We often use computers for daily purposes
Limited resources	14	There were limited technologies to use in our learning for one to one purpose. I should share computers with colleagues

As Table 5.20 indicates, most pre-service teachers mentioned teacher educators' technology integrated teaching practices had strongly influenced their learning with technology (N = 60). Teacher educators' practice as a factor was further investigated during the interviews with pre-service teachers. Pre-service Teacher 6 said:

We often prefer a method, which is more common and practiced in the CTE. We did not see the practice of teacher educators previously, hence, not sure how to use technology in learning. [Pre-service Teacher 6].

The results indicate multiple factors negatively influenced the likelihood of pre-service teachers learning using technology, including the lack of modelling by teacher educators'.

5.1.2.1.2. Kind of PD program teacher educators would like to attend. Teacher educators were asked in an open ended question to list and describe the kinds of PD programs they would like to attend that would help them to integrate technologies in their teaching. The qualitative responses were grouped under three main themes following the process illustrated in Section 4.6.2 of Chapter 4. Table 5.21 reports the theme, the number of responses the teacher educators mentioned the theme (N) and an illustrative examples/description. Teacher educators most frequently mentioned (N = 13) the need for PD programs focused on the use of technologies in teaching.

Table 5. 21

PD Programs Teacher Educators would like to Attend (N = 16)

Themes	N	Example response
Use of technology in teaching	13	Pedagogical use of technologies
Use of particular technology	3	Auto ware, MATLAB, E-lesson design, software that can be used to teach maths
Others	1	SPSS, programing

Interviews with teacher educators revealed similar desires about attending a PD program about using technology in teaching. For example, Teacher Educator 2 said:

The kind of PD programs organised in the CTE were emphasised on basic skill acquisitions like Microsoft Excel, SPSS. I prefer to attend a different PD like how to use technology in teaching. [Teacher Educator 2].

Some teacher educators showed an interest in attending a PD program focused on the use of particular software pertinent to mathematics teaching. For example, Teacher Educator 6 said:

Generic forms of PD programs are common in the CTE. PD programs relevant to the field of specialisation are often missed, for example, using technology in teaching mathematics. [Teacher Educator 6].

The results from the questionnaire and interview together showed that the teacher educators were interested in attending PD programs on the pedagogical use of technology in teaching and they preferred subject specific PD programs to general skill acquisition.

5.1.2.2. Describing the learning environment. The availability of technologies and the department's technology policy were analysed under this section.

5.1.2.2.1. Availability of technologies. As part of the learning context analysis, the availability of various technologies in the mathematics department for teaching purposes was identified at both CTEs. Teacher educator participants indicated that they could easily get internet access at their particular CTE. Moreover, the availability of some selected technologies and how often they used these technologies were identified as shown in Table 5.22 ordered as they appeared in the distributed questionnaire. The table also shows Frequencies (N), Mean (M) and Standard Deviation (SD).

Most teacher educators ($N = 13$) rated desktop computers with $M = 3.5$ and $SD = 0.35$ and data projectors with $M = 3.50$ and $SD = 1.09$ as freely accessible. Even though teacher educators indicated that some technologies were available for teaching purposes, they tended not to use them often in their teaching. For example, most teacher educators ($N = 13$) except those who did not answer some of the items, identified desktop computers as freely accessible ($N = 13$) but most ($N = 12$) never used computers in their teaching.

Table 5. 22

*Availability and Frequency of Use of Some Selected Technologies as Perceived by Teacher**Educators (N = 16)*

Technology	Availability*						Frequency of use**					
	N				M	SD	N				M	SD
	1	2	3	4			1	2	3	4		
Desktop computers	2	1	0	13	3.50	0.35	12	1	1	2	1.56	1.09
Laptops	13	2	0	0	1.13	0.35	15	1	0	0	1.13	0.50
Audio Equipment's	13	1	2	0	1.31	0.70	15	1	0	0	1.13	0.50
Digital Photo Camera	14	0	2	0	1.25	0.68	15	1	0	0	1.13	0.50
Mobile Phones	1	1	3	10	3.47	0.92	14	1	1	0	1.31	0.87
Data Projector	2	1	0	13	3.50	1.09	3	1	7	5	2.88	1.09
Systems												
Television	10	3	2	0	1.47	0.74	15	1	0	0	1.13	0.50

*1= Not available, 2 = Limited access, 3 = Are not accessible for teaching purpose, 4 = Free Access

**1 = Never, 2 = Once or twice per semester, 3 = About once every month, 4 = At least once per week

In addition, the availability and frequency of use of some selected web based learning resources is shown in Table 5.23 ordered as they appeared in the distributed questionnaire. Some items were not answered by all of the teacher educators. The table also shows the Mean (M) and Standard Deviation (SD) values for the availability and frequency of use of some selected technologies in teaching. The teacher educators tended to have ready access to YouTube (M = 3.93, SD = 1.14) and social learning communities (M = 3.64, SD = 0.49); they were not, however, using these learning resources in their teaching very often.

Similar results to those shown in Tables 5.22 and 5.23 were found in the focus group discussion with teacher educators.

Table 5. 23

*Accessibility and Frequency of Use of Web Based Learning Resources Perceived by Teacher**Educators (N = 16)*

Technology	Availability*						Frequency of use**					
	N				M	SD	N				M	SD
	1	2	3	4			1	2	3	4		
YouTube	1	0	4	9	3.57	0.64	14	1	0	0	1.13	0.52
Weblogs	9	2	0	2	1.77	1.24	15	1	0	0	1.00	0.00
Social Learning Communities	0	0	5	9	3.64	0.49	13	2	0	0	1.13	0.35
Search Engine	0	2	1	11	3.64	0.74	5	2	5	4	2.50	1.21
Email	0	2	2	10	3.57	0.75	11	1	3	0	1.67	1.23
Chat Rooms	10	2	1	0	1.50	0.94	14	0	0	0	1.00	0.00
GeoGebra	11	1	0	0	1.08	0.29	13	0	0	0	1.00	0.00
Microsoft Mathematics	8	2	0	3	1.85	1.28	13	2	0	0	1.13	0.35
Spreadsheets Like Excel	0	0	2	11	3.84	0.37	11	3	0	1	1.40	0.83
PowerPoint Slides	0	0	4	10	3.71	1.12	11	1	1	2	1.60	1.12

*1= Not available, 2 = Limited access, 3 = Are not accessible for teaching purpose, 4 = Free Access

**1 = Never, 2 = Once or twice per semester, 3 = About once every month, 4 = At least once per week

The teacher educators indicated technologies were available but acknowledged that these were not often used for teaching purposes. Typical responses during the discussion were:

I can access computers and some free software as there is an internet connection.

However, I did not get the time and the chance to use these technologies in my teaching.

[Teacher Educator 2].

I think my limited practice of technology integrated teaching was not due to limited availability of technologies. There are computers and internet connection (that can

facilitate to download software). Nevertheless, I have never considered teaching with technology in practices.[Teacher Educator 1].

In a similar way, pre-service teachers were asked to rate the availability and use of a range of technologies in their learning. The availability and frequency of use of some selected technologies by pre-service teachers is shown in Table 5.24 ordered based on their appearance in the distributed questionnaire. The availability and frequency of use of the technologies are shown in terms of the number of pre-service teachers who rated the scale (N) with a few none responses on some items, Means (M) and Standard Deviations (SD).

Table 5. 24

Availability and Use of Technologies Perceived by Pre-Service Teachers (N = 120)

Technology	Availability*						Frequency of use**					
	N				M	SD	N				M	SD
	1	2	3	4			1	2	3	4		
Desktop computers	25	31	39	24	2.52	1.01	87	12	2	15	1.36	0.09
Laptops	56	21	34	6	1.91	0.98	97	3	2	12	2.13	0.60
Audio Equipment	52	20	24	19	2.08	1.15	98	9	1	6	1.53	0.75
Digital Photo Camera	88	7	13	8	1.50	0.97	107	3	1	6	1.33	0.60
Mobile Phones	54	19	17	27	2.15	1.20	87	7	4	15	2.31	0.88
Data Projector Systems	5	28	58	21	2.85	0.79	84	7	11	12	2.88	1.99
Television	61	22	21	14	1.91	1.01	102	5	3	6	2.13	0.67

*1= Not available, 2 = Limited access, 3 = Are not accessible for teaching purpose, 4 = Free Access

**1 = Never, 2 = Once or twice per semester, 3 = about once every month, 4 = At least once per week

Pre-service teachers perceived less availability of selected technologies in their CTE for learning than did the teacher educators. For example, most pre-service teachers (N = 70) indicated that access to desktop computers was either limited or that they were not accessible for

teaching purposes. Consequently, most pre-service teachers ($N = 87$) reported less opportunity to use them in their learning than did the teacher educators.

Pre-service teachers were also asked to rate the accessibility and frequency of use of the web based learning resources. The results are shown in Table 5.25, which shows the number of pre-service teachers who chose each category (N) with a few non responses on some items, Mean (M) and Standard Deviation (SD).

Table 5. 25

Accessibility and Frequency of Use of Selected Learning Resources Perceived by Pre-Service Teachers ($N = 120$)

Technology	Availability*						Frequency of use**					
	N				M	SD	N				M	SD
	1	2	3	4			1	2	3	4		
YouTube	68	13	21	3	1.62	0.93	99	4	2	5	1.20	0.69
Weblogs	66	16	19	4	1.64	0.94	98	2	3	6	1.24	0.75
Social Learning Communities	52	20	28	8	1.94	1.00	87	6	8	10	1.47	0.97
Search Engine	67	17	21	4	1.66	0.94	99	4	6	4	1.24	0.71
Email	64	18	22	5	1.72	0.92	97	3	5	7	1.30	0.82
Chat Rooms	69	17	17	5	1.62	0.94	99	3	7	4	1.25	0.72
GeoGebra	78	13	14	4	1.49	0.85	99	6	3	3	1.19	0.61
Microsoft Mathematics	64	16	19	11	1.80	1.08	92	8	5	6	1.32	0.80
Spreadsheets Like Excel	60	22	22	6	1.77	0.98	93	11	4	4	1.28	0.70
PowerPoint Slides	61	16	20	12	1.85	1.01	87	6	10	9	1.47	0.98

*1= Not available, 2 = Limited access, 3 = Are not accessible for teaching purpose, 4 = Free Access

**1 = Never, 2 = Once or twice per semester, 3 = about once every month, 4 = At least once per week

The pre-service teachers generally perceived less availability of the resources to support their learning of mathematics than the teacher educators did. For example, although teacher educators perceived the availability of YouTube for learning in Table 5.23 ($M = 3.57$, $SD = 0.64$), a large number of pre-service teachers ($N = 68$) indicated that YouTube was not available ($M = 1.62$, $SD = 0.93$) to support their learning of mathematics. As a result, most indicated ($N = 99$) that they had never used YouTube in their learning of mathematics.

5.1.2.2.2. The department's policy on the use of technology in teaching. The Ministry of Education (MOE) in Ethiopia was encouraging teacher educators' to use technologies in their teaching to increase the quality of education (MOE, 2008). In this context, teacher educators perceived that the department of mathematics in the two CTEs to attach at least some importance ($N = 16$) to the use of technology in teaching mathematics as shown in Table 5.26. Nevertheless, these technologies were not being used.

Table 5. 26

Importance of Technologies in Teaching by the Department ($N = 16$)

Rate	N	Percent
No Importance	0	0
Some Importance	6	37.5
Great Importance	7	43.8
Very Great Importance	3	18.8
Total	16	100.0

5.2. Design, Pre-implementation Refinement and Improvement of the PD Program

Section 5.1 described the process of context analysis, which supported the designing of the first PD program prototype I. The section focuses on the design and formative evaluation of the PD program guidelines based on the context analysis results and their subsequent refinement.

This section further explains the involvement of teacher educator participants, ICT coordinators and experienced mathematics education professors to further improve the PD program. It contains three sub sections. The first Section 5.2.1, describes the appraisal of the PD program design guidelines and their improvement. Section 5.2.2 describes additional PD program guidelines suggested by teacher educators and experts. Finally, Section 5.2.3 summarises and concludes the major findings of the section.

5.2.1. PD program design guidelines and implications for the PD program. The context analysis was used to design the first PD program, Prototype I. Smith and Ragan's (2005) domains of context described in Table 4.1 in Chapter 4, Section 4.2, were applied to describe and analyse the context and later to suggest PD program guidelines.

As shown in Section 5.1, one of the factors considered for the learner context analysis was their beliefs about the importance of technology in learning. Both teacher educators and pre-service teachers indicated that technology could make a greater contribution to learning. This belief constituted a favourable condition for the implementation of technology integrated teaching. In addition, beliefs about the use of technology in teaching influenced teacher educators' practices.

The teacher educators' and pre-service teachers' TPSA was another variable considered in the learners' analysis. Both teacher educators and pre-service teachers indicated their agreement that they were proficient in relation to most of the TPSA items. Both groups of participants, however, were unsure about using particular software applications including GeoGebra for teaching or learning mathematics.

The questionnaire and interview results indicated that teacher educators often used technologies for non-pedagogical use. This finding implied that the PD program should focus on the application of discipline based software for pedagogical use. Teacher educators further indicated that there were readily available technologies and the web based learning resources at the CTEs, but those technologies were not used for teaching purposes. The availability of such technologies, however, was a potential asset for further technology integrated teaching practices when scaffolded with a PD program.

The teacher educators' context in relation to their STAMPK before participating in a PD program and the kinds of PD programs they had attended in relation to technology was also taken as part of the teacher educators' context. Teacher educators perceived themselves, on average, to have knowledge in the SMK, SPK and SPMK categories. They were, however, unsure of their competencies in relation to the TK, STPK, and STMK constructs. Similar results were found during the observation. Teacher educators showed limited practices in explicitly demonstrating TK, STPK, STMK and STAMPK in their teaching. These finding suggested that the PD program needed to emphasise the pedagogical use of technology in teaching. In addition, the PD program should focus on how technology, pedagogy and content interplay in a classroom context for effective teaching of mathematics. The teacher educators indicated that they had often attended PD programs that emphasised general technology skill acquisition including use of SPSS, but not programs designed for pedagogical use or the pedagogical use of general of technology.

The findings indicated that lack of experiences with, and awareness of, the pedagogical use of technology as well as a lack of PD programs focused on these aspects were the most

frequently listed factors influencing teacher educators to use technology in their teaching. These factors were considered in designing the PD program. Some teacher educators also indicated their interest in participating in PD program which had an emphasis on discipline, based software. This was addressed by incorporating exemplar mathematics software in the PD program.

Based on this analysis, design guidelines were devised to shape the designing of the first PD program (Prototype I). Table 5.27 summarises the domains of context analysis (Domains), major findings and design guidelines implications. The following were the basic guidelines of the suggested PD program (Prototype I).

- Focus on pedagogical use of technology and avoid basic skill acquisition
- Preparation of exemplar material
- Emphasis on available technology and tools
- Consideration of software freely available on the web

The next section reports the results of the evaluation and revision process of the PD program (Prototype I) suggested in Section 5.2.1, as described in Section 4.2 of Chapter 4. The evaluation and revision involved the participating teacher educators, ICT coordinators and two experienced mathematics education professors. The mathematics education professors, primarily made suggestions related to the exemplar material (see Appendix N). Teacher educators and ICT coordinators in the study had the opportunity to revise and comment on the PD program guidelines during an initial workshop.

Table 5. 27
Major Findings and Design Guidelines Implications

Domains	Major findings	Design guidelines implications
Learners context	On average both teacher educators and pre-service teachers perceived themselves proficient in most of the items of TPSA	The PD program should avoid emphasis on basic skill acquisition
- Perceived proficiency with technology (TPSA)		
- Teacher educators' STAMPK	Teacher educators were likely to indicate competence in SMK, SPK and SPMK but to be unsure or disagree that they were competent concerning TK, STPK, STMK and STAMPK	The PD program should focus on pedagogical use of technology, and its interplay with pedagogy and content
- Beliefs about the contribution of technology to learning	Positive beliefs of both teacher educators and pre-service teachers regarding the use of technology in teaching and learning	The PD program should strengthen their positive beliefs
- Factors influencing the integration of technology in teaching	Lack of experience and awareness Lack of pedagogically focused PD program on technology	The PD program should indicate the provision of exemplar material indicating the design process of an technology integrated lesson The PD program should be focused on pedagogical use of technology

Learning context analysis		
- Availability of technologies	<p>Availability of overhead projectors, mobile phones and desktop computers</p> <p>Free internet access</p> <p>No software resources</p>	<p>The PD program should focus on the use of overhead projector, desktop computers and mobile phones in the design of the PD program</p> <p>The PD program should focuses on the use of free and discipline based software available on the web</p>
- Teacher educators needs of PD program	<p>Teacher educators were required to attend the PD program in the pedagogical use of technology in mathematics</p>	<p>The PD program should include mathematics based software as an example in the PD program</p>

5.2.2. Appraisal of PD program design guidelines: Design of Prototype II. As described in Section 5.2.1, the design guidelines facilitated the start of the PD program and allowed for further discussion and improvement. Teacher educators reviewed each guideline for possible improvement and later for implementation of the revised PD program. The following sections discuss each guideline and suggested improvements.

5.2.2.1. A PD program focused on pedagogical use of technology. As was evident from the literature reviewed in Chapter 3, Section 3.5.1, seminars or workshops that focus on developing operational skills about specific educational software are not sufficient to help teachers to use technology in teaching. Similarly, teacher educator participants indicated their interest in attending a PD program that focused on the interplay of technology, pedagogy and content knowledge. Teacher educators agreed on the importance of excluding basic skill acquisition from the PD. Rather, as Table 5.21 showed, teacher educators (N = 13) were interested in attending a PD program which emphasised pedagogical use of technology rather than basic skills. In addition, during the interviews, teacher educators indicated that basic to using technology in teaching is an understanding of ‘how technology fits with the pedagogy and content’. Table 5.28 provides illustrative examples of teacher educators’ responses provided during Workshop 1 to the question “What kind of PD program do you suggest?”

Table 5. 28

Kind of PD Program Preferred by Teacher Educators

Teacher educator	Illustrative responses
4	I am happy if a PD program is conducted could be related to how to use technologies in teaching
8	There should be a PD program about the use of technology in teaching
9	Any PD program that enables me to integrate technology in my teaching is appreciated
10	A PD program, which focused on how to use various technologies for teaching purposes like computers, mobile phones, and software, is the one I preferred most.
11	I need to get support on how to use different technologies in teaching mathematics and Internet for teaching purposes beyond email and browsing

The teacher educators further indicated that they had attended PD programs pertinent to technical skills (see Table 5.15) but that such PD programs did not support their use of technology in teaching. For example, during interview Teacher Educator 3 said:

I have attended many PD programs on technology, none of them, however, helped me to try to practice in my own teaching. [Teacher Educator 3].

In a similar way, teacher educators indicated their interest in attending a PD program that focused on the use of technology in teaching and its interplay with the pedagogy and content. Teacher educators' responses to the questionnaire items concerning TK, STPK, STMK, and STAMPK from the questionnaire and classroom observations supported this. Table 5.29 summarises the relevant results from Tables 5.12 and 5.13.

Table 5. 29

Teacher Educators' Perceived Knowledge in Technology and its Interplay with Content and Pedagogy

Component	Questionnaire*		Observation**
	M	SD	Mode
TK	3.04	1.08	2
STPK	1.90	0.79	1
STMK	2.14	0.71	1
STAMPK	2.08	0.74	1

*1 = Strongly disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly Agree

**1 = Not observed, 2 = Partly observed, 3 = Observed

The teacher educators agreed that consideration of the influence of technology on pedagogy and content should be an important point of discussion during the PD program. As a result, the teacher educators recommended that discussion of the STAMPK framework should be part of the PD program.

5.2.2.2. Inclusion of exemplar material. Exemplar material (see Appendix N) was designed as an example for teacher educators to use in their mathematics teaching of pre-service teachers using technology. The exemplar material was designed and distributed before the initial workshop to enable and encourage teacher educators to use the available technologies in their teaching. The exemplar material addressed using technology as a basis for delivering the lessons and facilitating the learning activities of pre-service teachers. Its use was aimed at helping pre-service teachers and assisting them to understand the implications of technology in today's society, empowering them to think about mathematics, supporting them to lead their own learning and career paths and to make their students learning easier. Finally, a 2 hour lesson plan was included in the design of the exemplar material. The aim of the lesson was to support pre-

service teachers to: i) construct knowledge from their experience ii) interpret the world with respect to their own experience; iii) actively involve and develop meaning on the basis of their experiences; iv) work collaboratively to share multiple ideas and negotiate on different perspectives to form meaning; v) learn in a realistic settings; and vi) assess their own progress. In addition, consideration of context as an important aspect to consider while using technology in teaching, and was incorporated in the exemplar material. Context was considered to include understanding the pre-service teachers' prior knowledge of how technology can be used to build on existing knowledge and the use of the available technologies. The exemplar material was also designed based on the context and conditions at the two CTEs. Table 5.30 illustrates this along with how these considerations informed the exemplar material.

Table 5. 30

Practical Considerations in the Exemplar Material

Context	Practical considerations in design of the exemplar material
Accessibility of internet	Use mathematical software which is available on the web
Large class size with fewer computers	Pre-service teachers are encouraged to work in groups on a computer
Less awareness on technology integrated lessons	Use of software which does not demand advanced skill from both pre-service teachers and teacher educators
Limited access to specialised mathematical software	The exemplar material was aimed at designing lessons with the available resources
Alignment with interest of the school policy	The CTE teacher educators are encouraged to use available technologies in the teaching learning process

Further, an example of technology integrated lesson plan (see Appendix N) was designed based on the contexts listed in Table 5.30. The teacher educators and two mathematics education

professors separately discussed the draft exemplar material with a view to suggesting further improvements. Their reflections are presented in the following sections.

5.2.2.2.1. *Teacher educators' and mathematics education professors' reflection on the exemplar material.* One of the purposes of the first workshop was to invite teacher educators to reflect on and revise the exemplar material by responding to each of the intended purposes listed in Table 5.31. The table also shows illustrative reflections on the exemplar material and the teacher educator that provided the illustrative reflection.

Table 5. 31

Teacher Educators' Reflection on the Exemplar Materials

Intended purposes	Illustrative reflection	Teacher educator
Create a clear understanding of technology integrated teaching	The example included considered our context, hence, could be used as guidelines to design similar lessons	3
Provide a concrete example for the execution of technology integrated lessons	The example is from the content where pre-service teachers are currently attending. This makes the exemplar material more relevant	8
Stimulate to technology integrated teaching practice	It is a good point of reference for us as we did not practice technology integrated teaching previously	4

Table 5.31 indicates that teacher educators believed the exemplar material would be helpful and relevant for designing similar technology integrated lessons, and perform similar activities. Teacher educator 9 suggested improvements to the exemplar material when he said:

The example is only based on geometry concept. It could be wise to add more examples like from algebra to make the exemplar material more comprehensive. [Teacher Educator 9].

Although Teacher Educator 9 suggested an improvement in the exemplar material, most of the teacher educators agreed that the presented examples were sufficient to start to implement technology integrated teaching.

Similarly, two experienced Mathematics Education Professors as experts commented on the exemplar material. The discussion focused on the purposes of the exemplar material as shown in Table 5.31. The importance of the exemplar material in relation to creating understanding about technology integrated teaching was one of the focuses on the discussion. In this regard, Mathematics Education Professor 1 said:

I liked the way it laid out the steps... Other teacher educators in Ethiopia will be able to use it as well.... [Mathematics Education Professor 1].

Mathematics Education Professor 2 commented on the need to improve the procedure for selecting problems in the exemplar material to use problem based learning as a method of teaching:

Problem based learning is appropriate pedagogical approach to promote... the question is what are the kinds of problems that you promoting, if you take a problem based learning approach.... [Mathematics Education Professor 2].

Further, Mathematics Education Professor 1 commented on the importance of considering the CTEs contexts in designing the exemplar material to provide concrete concepts and examples.

The fit of the material with the context... It seems like good stuff to give to teacher educators in any way really... [Mathematics Education Professor 1].

The importance of including lesson plan format at the end of the exemplar material was emphasised by Mathematics Education Professor 1. She advised this could support teacher educators who are new to technology integrated teaching approach. She said:

I wonder if it would help to include an example of a lesson filled on that format...
[Mathematics Education Professor 1].

Taking into account the comments from mathematics education professors and teacher educators the material was refined to be delivered to teacher educators after Phase 1.

5.2.2.3. *Emphasis on available technologies and tools.* This guideline was discussed with teacher educators as it was drawn from questionnaire and interview results. Teacher educators cited limited availability of a variety of technologies as one of the factors impeding the use of technology in their teaching. Computers were the most available technologies in the CTEs. Teacher Educator 5 indicated this during the interview. He said:

It could be impractical if we consider technologies, which are more advanced and costly, which we cannot use due to our limited skill and accessibly. [Teacher Educator 5].

During the first workshop, teacher educators also frequently mentioned the importance of using readily available technologies in their teaching. Teacher Educator 9 said:

We had better consider technologies that we can easily access and fit with our context.
[Teacher Educator 9].

Pre-service teachers and teacher educators were acquainted with such technologies as computers, and overhead projectors that were considered in designing the PD program. During

the interview teacher educators suggested considering computers for technology integrated teaching. For example, Teacher Educator 6 said:

The most accessible technology in the CTE is computers. Considering computers in the PD process is worthwhile. [Teacher Educator 6].

Hence, the availability of such technologies in the CTEs was taken into account in the design and implementation of the PD program.

5.2.2.4. A PD program considering software freely available on the web. A great deal of mathematics specific software and many technology based learning environments can provide opportunities for active learning and enhanced student engagement. For instance, simulations and animations enable students to vary a selection of input parameters, observe how each affects the system under study, and interpret the output results through an active process of hypothesis making, and testing ideas. They can explore combinations of factors and observe their effects on the evolution of the system under study. Mathematics specific software includes GeoGebra, Microsoft Mathematics, Maxima, STELLA, and spreadsheets. Some of these are free, Microsoft Mathematics, for example, (<http://www.microsoft.com/en-au/download/details.aspx?id=15702>) is free software that can support students to achieve an understanding of a range of mathematical concepts.

In Ethiopia, financial constraints mean that freely available software is preferable. Microsoft Mathematics was selected for inclusion in the exemplar material because it fit this criterion and had capabilities thought to be useful in enhancing the teaching of mathematical ideas. Teacher Educator 3 said:

The availability of internet access in the CTE is an opportunity to consider freely available software on the web. [Teacher Educator 3].

Teacher Educator 5 also indicated that in Ethiopia, financial constraints mean that freely available software was preferable to use in teaching.

Considering freely available software on the web is meant for considering financial constraint of the CTE. [Teacher Educator 5].

5.2.3. Additional guidelines suggested by teacher educators. In addition to improvement to the PD program guidelines as explained in Section 5.2.1, teacher educators suggested additional PD program guidelines. The suggested guidelines were i) formation of teams, ii) consistent support from ICT coordinators and iii) emphasis on an informal PD program fitting with their regular schedule. Each is discussed below.

5.2.3.1. Formation of teams. Teacher educators cited team formation during the focus group discussion as a strategy to carry out the PD program effectively. Teacher Educator 3 said:

Rather than conducting a PD program involving all teacher educators at the same time and place, which is difficult for its practicality, I prefer formation of teams based on our office arrangement. [Teacher Educator 3].

The suggestion provided by Teacher Educator 3 was supported by most of the teacher educators. For example, Teacher Educator 4 said:

I can easily discuss about my technology integrated teaching practices and its challenges with my upfront friend in my office. [Teacher Educator 4].

Five teams were therefore, formed (three in College 1 and two in College 2) based on office locations. Teacher educators also suggested that four key characteristics of the teams

should be considered which could contribute to the proper functioning of the teams in supporting their effort to integrate technology in their teaching. These characteristics were involvement, collaboration, positive attitude and motivations, and clear and shared visions of the teams. Formation of teams was, therefore, considered to be one of the basic PD program guidelines in the actual implementation.

5.2.3.2. Support from ICT coordinators. Before teacher educators participated in the PD program, they were asked to list the kind of support provided by ICT coordinators. The findings indicated that support from ICT coordinators was limited to solving technical problems. It was found that ICT coordinators rarely supported teacher educators in relation to the pedagogical use of technology. For example, Teacher Educator 5 said, during the interview, the support from ICT coordinators as:

ICT coordinators were busy in supporting us on technical issues. I have never asked them to pedagogical support and there was no initiative from the ICT coordinators to support pedagogical use of technology in teaching. [Teacher Educator 5].

The quote from Teacher Educator 5 indicates that his belief was that it is appropriate for technology support to focus on pedagogy.

The ICT coordinators were also asked about the kind of support they provided for teacher educators. The following were illustrative responses from the ICT coordinators. All the responses indicated that pedagogical use of technology was given less emphasis both in the design of PD program as well as in relation to the support provided by the ICT coordinators:

Mainly teacher educators required support on troubleshoot issues and technical problems. These include installing software, PD programs on Microsoft offices and others. I have

never considered, however, supporting teacher educators on pedagogical use of technology. [ICT coordinator 2].

I often support and asked to support on technical problems of technology than the pedagogical use of technology. Once we have prepared a PD on e-lesson, but I have never seen teacher educators using these applications in their teaching. [ICT coordinator 3].

We often support teacher educators in formal and informal ways. We organised a PD program in different areas of technology applications including Microsoft office applications, e –lessons. Informally, we have supported teacher educators on their daily technical problems, particularly computer and its peripheral problems. [ICT coordinator 1].

Due to limited support for the pedagogical use of technology from ICT coordinators, teacher educators suggested including continuous support from ICT coordinators while the PD program was in progress. This was incorporated in the program. For example, at College 2, a schedule showing the availability of ICT coordinators was prepared to support teacher educators. It is shown in Table 5.32. In this particular CTE, there were three ICT coordinators, three ICT centres (labs) and all of the ICT coordinators were working every weekday and Saturday.

Table 5. 32

A Schedule to Support Teacher Educators by ICT Coordinators

Dates	Time and centres		
	Lab 1	Lab 2	Lab 3
Monday	2:00 – 6:00	11:40 - 6:00	10:30 – 12:00
Tuesday	2:00 – 6:00	10:30 – 6:00	12:00 – 6:00
Wednesday	2:00 – 6:00	02:00 – 4:00	02:50 – 6:00
Thursday	-	08:00 – 2:00 and 4:00 - 6:00	12:00 – 6:00
Friday	-	-	12:00 – 6:00
Saturday	-	8:00 – 6:00	-

5.2.3.3. *Emphasis on informal PD program setup.* The teacher educators suggested a different kind of PD program, which did not require their regular physical presence in the same place at the same time. For example, during the initial workshop Teacher Educator 7 said:

Rather than attending a PD program with the sense of togetherness, it could be more effective if we are able to refer when required. We could discuss issues about technology integrated teaching with the fellow teams formed and with other teams informally when required. [Teacher Educator 7].

Teacher Educator 5 also indicated, during the workshop, that an informal PD program was workable in their context, as they had varied teaching schedules and found it difficult to meet at the same time:

It could be difficult to carry out a PD program involving all teacher educators at the same time for prolonged periods. This is because there is no appropriate time where teacher

educators are free at the same time. Hence, I recommend informal discussion with you and with other teams to conduct an effective PD program. [Teacher Educator 5].

Participating in an informal PD program, therefore, was the preferred approach by teacher educators rather than a formal PD program requiring their regular attendance and demanding their togetherness.

In general, using the results obtained from the context analysis in Section 5.1 and literature review in Chapter 3, the guidelines for the first PD Prototype I were formulated. Later, the first prototype guidelines were passed through subsequent revision and redesign in collaboration with teacher educators and experienced mathematics education professors as outlined in Section 5.2. The formative evaluation and redesign was conducted during and following the first interview, the first workshop and group discussion sessions. Further, mathematics education professors reflected and suggested redesign ideas on the exemplar material. Figure 5.2 shows the formative evaluation process of the PD program and its implementation.

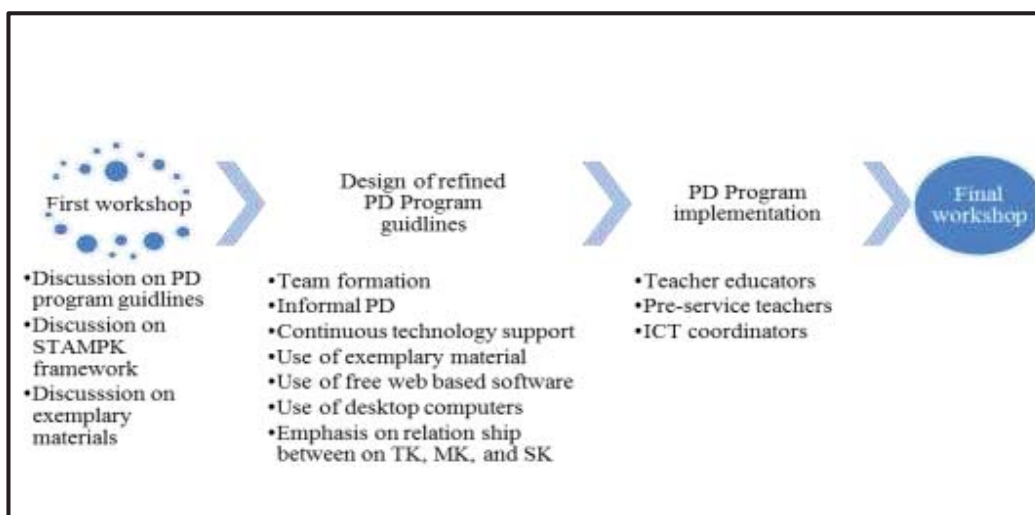


Figure 5. 2. Formative evaluation process of the PD program.

The final PD program was supported and guided by the above PD program guidelines in addition to the principles of effective PD programs reviewed in Chapter 3.

The next section, Section 5.3 presents the results found after the teacher educators had participated in the revised PD program. The section presents and compares teacher educators' technology integrated teaching practices before and after participating in the revised PD program.

5.3. Impact Evaluation of the Revised PD Program

Section 5.2 described the PD program and how it was revised following participants and experienced mathematics education professors' feedback. This section illustrates the impact the PD program had on teacher educator technology integrated teaching and pre-service teachers' learning. The summative evaluation was based on the results obtained from individual interviews, questionnaires, focus group discussions, observation sessions, and the final workshop after the teacher educators participated in the PD program. As discussed in Chapter 4, Section 4.4, the data were both qualitative and quantitative in nature. The qualitative data were analysed by formation themes and categories inductively as explained in Chapter 4, Section 4.6.2, whereas the quantitative data were analysed using SPSS to calculate Mode, Frequencies (F), Mean (M), Standard Deviation (SD), paired sample t -test and Cohen's d .

5.3.1. Teacher educators' STAMPK after participating in the PD program. Teacher educators were asked to rate their STAMPK after participating in the PD program which lasted for 5 months. Tables 5.33 to 5.39 shows their perceived knowledge of each STAMPK construct reported in terms of Number of teacher educators who responded in each of the five possible categories to a particular item (N), Mean of Means (M) and Standard Deviation (SD) of each

construct of STAMPK. In each of Tables 5.33 to 5.39, the means are ordered from highest to lowest.

5.3.1.1. Teacher educators' Technology Knowledge (TK). Table 5.33 shows that teacher educators overall moderately agreed that they had TK (overall $M = 3.38$, $SD = 1.01$) after participating in the PD program.

For a single item, for example, the teacher educators tended to agree that they have the knowledge to keep up with important technologies after participating in the PD program (Item 3, $M = 3.50$, $SD = 0.89$).

Table 5. 33

Teacher Educators' TK after Participating in the PD Program

No.	Item	N					M	SD
		1	2	3	4	5		
7	I have had sufficient opportunities to work with different technologies	0	5	3	8	0	4.31	0.77
2	I can learn technology easily	0	2	1	12	0	3.75	0.77
3	I keep up with important new technologies	0	4	0	12	0	3.50	0.89
1	I know how to solve my own technical problems	0	2	5	9	0	3.45	0.73
6	I have the technical skills I need to use technologies	0	5	3	8	0	3.19	0.91
4	I frequently play with technologies	2	7	1	5	1	2.75	1.23
5	I know about many different technologies	1	8	2	5	0	2.69	1.00
	Overall mean response						3.38	1.01

5.3.1.2. Specialised Mathematics Knowledge (SMK). As shown in Table 5.34, teacher educators tended to agree that overall they had SMK ($M = 4.00$, $SD = 0.69$). This result was similar to that before the PD program (Table 5.6, $M = 3.90$, $M = 0.61$). Because the PD program

was not intended to address SMK and the teacher educators reported relatively high levels of initial proficiency, this result is not surprising.

With respect to individual items, teacher educators on average agreed that they had sufficient knowledge about mathematics both before (Item 8, $M = 4.25$, $SD = 0.45$) and after ($M = 4.19$, $SD = 0.54$), showing highest mean score compared to other items.

Table 5. 34

Teacher Educators' SMK after Participating in the PD Program

Item No	Item	N					M	SD
		1	2	3	4	5		
8	I have sufficient knowledge about mathematics	0	0	1	11	4	4.19	0.54
12	I understand the difference between the knowledge required for teaching mathematics and common knowledge for mathematics	0	1	1	10	4	4.06	0.77
10	I have various ways of developing my understanding of mathematics	0	1	1	11	3	4.00	0.73
9	I can use a mathematical way of thinking	0	1	1	12	2	3.93	0.68
11	I have a mathematical knowledge unique to teaching	0	1	3	10	2	3.81	0.75
	Overall mean response						4.00	0.69

5.3.1.3. Specialised Pedagogical Knowledge (SPK). Similar to their perceived SPK before participating in the revised PD program (see Table 5. 7), the teacher educators agreed that after participating in the revised PD program they had SPK as defined by all items of SPK (Overall $M = 3.82$, $SD = 0.71$).

They agreed to have the knowledge, for example, to use a wide range of teaching approaches in a classroom setting both before (Item 17, $M = 3.69$, $SD = 0.87$) and after ($M = 3.50$, $SD = 0.82$) participating in the revised PD program (see Table 5.35).

Table 5. 35

Teacher Educators' SPK after Participating in the PD Program

Item No	Item	N					M	SD
		1	2	3	4	5		
13	I know how to assess pre-service teachers' performance in a classroom	0	1	1	13	2	4.06	0.44
19	I know how to manage a classroom	0	1	1	11	3	4.00	0.73
14	I can adapt my teaching based upon what pre-service teachers currently understand	0	1	2	11	2	3.88	0.72
18	I am familiar with pre-service teachers' common misconceptions	0	0	4	10	2	3.88	0.62
16	I can assess pre-service teachers' learning in multiple ways	0	2	1	12	1	3.75	0.77
15	I can adapt my teaching style to different learners.	0	2	2	11	1	3.69	0.79
17	I can use a wide range of teaching approaches in a classroom setting	0	3	2	11	1	3.50	0.82
	Overall mean response						3.82	0.71

5.3.1.4. Specialised Pedagogical Mathematics Knowledge (SPMK). Similar to the results found in Table 5. 8, Table 5. 36 shows that teacher educators agreed perceived that they had the knowledge on all items of SPMK after participating in the revised PD program. Teacher educators, for example, agreed that they had the knowledge to select an effective teaching approach to guide pre-service teachers' mathematics learning both before (Item 20, M = 3.93, SD = 0.25) and after (M = 3.88, SD = 0.62) participating in the revised PD program.

Table 5. 36

Teacher Educators' SPMK after Participating in the PD Program

No.	Item	N					M	SD
		1	2	3	4	5		
20	I can select effective teaching approaches to guide pre-service teachers' thinking and learning in mathematics.	0	1	1	13	1	3.88	0.62
24	I can anticipate mathematical concepts that pre-service teachers will find confusing	0	2	0	13	1	3.81	0.75
21	I can use a wide range of teaching approaches to teach mathematics	0	2	2	11	1	3.69	0.79
22	I can solve pre-service teachers' mathematical misconceptions using appropriate pedagogy/teaching.	0	1	1	12	2	3.69	0.60
23	I can anticipate what pre-service teachers are likely to think and choose appropriate teaching approaches	0	3	0	12	1	3.69	0.87
25	I can prevent pre-service teachers learning difficulties with appropriate teaching method	0	2	2	11	1	3.69	0.79
	Overall mean response						3.82	0.73

5.3.1.5. Specialised Technological Mathematical Knowledge (STMK). In contrast to their, on average, disagreement with all the items related to STMK (see Table 5.9) before participating in the revised PD program, teacher educators agreed with most of these items after the PD. For example, on average, they perceived that they had the knowledge to select technologies to use in teaching that enhances pre-service teachers learning of mathematics. After participating in the PD program the results (Item 28, $M = 3.69$, $SD = 0.60$) were very different from those before ($M = 1.81$, $SD = 0.83$). Table 5.37 shows the summary.

Table 5. 37

Teacher Educators' STMK after Participating in the PD Program

No.	Item	N					M	SD
		1	2	3	4	5		
28	I can select technologies to use in my classroom that enhance what I teach	0	3	1	12	0	3.56	0.81
30	I know how to cement the knowledge needed to teach mathematics with the application of technologies.	0	3	3	9	1	3.50	0.89
26	I know about technologies that I can use to develop pre-service teachers' understanding of mathematics.	1	2	3	10	0	3.38	0.96
27	I can use a wide range of technologies to teach mathematics	1	5	4	7	0	3.13	0.89
29	I cannot think of teaching mathematics without the use of technology	1	7	6	2	0	2.56	0.81
	Overall mean response						3.23	0.93

On the other hand, although the teacher educators, on average, disagreed that they had the knowledge to use a wide range of technologies before participating in the revised PD program (Item 27, $M = 1.56$, $SD = 0.63$), they were equivocal as to whether they had such knowledge after participating in the PD program ($M = 3.13$, $SD = 0.89$), although the item score had improved.

5.3.1.6. Specialised Technological Pedagogical Knowledge (STPK). Table 5.38 shows that teacher educators tended to agree with all items of STPK after participating in the revised PD program (Overall $M = 3.59$, $SD = 0.28$) in contrast to their overall disagreement prior to the PD program (Table 5.10, $M = 1.90$, $SD = 0.79$).

Table 5. 38

Teacher Educators' STPK after Participating in the PD Program

No.	Item	N					M	SD
		1	2	3	4	5		
35	I can adapt the use of the technologies to different teaching activities	0	1	4	10	1	3.69	0.70
36	I can select technologies that enhance how I teach.	0	1	3	12	0	3.69	0.60
31	I can choose technologies that enhance the teaching approaches for a lesson	0	2	4	9	1	3.56	0.81
33	Teaching pre-service teachers has caused me to think more deeply about how technology could influence the teaching approaches I use	0	2	3	11	0	3.56	0.73
34	I think critically about how to use technology in my classroom	0	2	4	9	1	3.56	0.81
32	I can choose technologies that enhance pre-service teachers' learning for a lesson	0	2	4	10	0	3.50	0.73
	Overall mean response						3.59	0.72

5.3.1.7. Specialised Technological and Mathematics Pedagogical Knowledge

(STAMPK). In contrast to their responses to STAMPK items before participating in the PD program (see Table 5. 11), Table 5.39 shows that after the PD, the teacher educators, on average, agreed with all items of STAMPK (Overall M = 3.59, SD = 0.82). The only item showing a less positive response was Item 40, concerning having the knowledge to provide leadership in helping others to teach technology integrated mathematics. For this item, there was, nevertheless, a greater tendency for the teacher educators to respond positively compared to before the PD.

Table 5. 39

Teacher Educators' STAMPK after Participating in the PD Program

No.	Item	N					M	SD
		1	2	3	4	5		
37	I can teach lessons that appropriately combine mathematics content, technologies and teaching approaches	0	2	2	11	1	3.69	0.79
38	I can choose technology to use in my classroom that enhances what I teach, how I teach and what pre-service teachers can learn	0	3	0	12	1	3.69	0.87
39	I can use strategies that combine mathematics content, technologies and teaching approaches.	0	2	1	13	0	3.69	0.70
41	I can understand pre-service teachers' misconceptions about mathematics concepts and can solve the misconceptions through the application of technology, which fit with a selected pedagogy	1	1	1	12	0	3.56	0.89
40	I can provide leadership in helping others to teach technology integrated mathematics with teaching approaches	1	1	6	8	0	3.31	0.87
	Overall mean response						3.59	0.82

The comparison of the teacher educators' perceived knowledge overall of each STAMPK construct before and after participating in the PD program is shown in Table 5.40. The results in Table 5.41 report Mean (M), *t*-test (*t*), degree of freedom (df), Standard Deviation (SD), Significance (*p*) and effect size for changes in each STAMPK construct for before and after teacher educators participated in the PD program are also included.

Table 5. 40

Teacher Educators' STAMPK before and after Participating in the PD Program (N = 16)

STAMPK Components	Before		After		Change			
	M	SD	M	SD	<i>t</i>	df	<i>p.</i>	Effect size(d)
TK	3.04	1.08	3.38	1.01	2.431	15	0.028*	0.16
SMK	3.90	0.61	4.00	0.69	0.594	15	0.561	0.07
SPK	3.75	0.71	3.82	0.71	0.305	15	0.765	0.05
SPMK	3.72	0.56	3.82	0.73	0.120	15	0.906	0.08
STPK	1.90	0.79	3.59	0.72	9.669	15	0.000**	0.75
STMK	2.14	0.71	3.23	0.93	7.190	15	0.000**	0.55
STAMPK	2.08	0.74	3.59	0.82	5.663	15	0.000**	0.70

* $p < 0.05$, ** $p < 0.01$

As Table 5.40 depicts there were statistically significant changes in TK, STPK, STMK, and STAMPK with substantial effect size. Cohen (1988) hesitantly defined effect sizes as 'small, $d = 0.2$,' 'medium, $d = 0.5$,' and 'large, $d = 0.8$ '. For example, the mean change in STPK ([$df = 15$] = 9.67, $p < 0.000$) is statistically significant with medium to large effect size (0.75). The components SPK, SMK and SPMK, however, did not show significant changes. These results appear to be due to the fact that the teacher educators perceived that they already had sufficient knowledge of these components before the intervention and the PD program placed less emphasis on these aspects. Although there was a mean change in some of the items of TK, the overall mean response indicated that on average teacher educators were unsure about having TK both before ($M = 3.04$, $SD = 1.08$) and after ($M = 3.38$, $SD = 1.01$) participating in the revised PD program, although some positive change was noted.

5.3.2. Teacher educators' use of technology. Teacher educators were asked how frequently they used the available technologies in their teaching after participating in the revised

PD program. The comparison of the frequency of use of technology in their teaching practices before and after participating in the revised PD program is shown in Table 5.41. The numbers of teacher educators' responses in each category for each of the item (N) are shown together with Mean (M), Standard Deviation (SD), degrees of freedom (df), paired sample *t* score and significance (*p*).

Table 5. 41

Frequency of Use of technology in Teaching before and after Participating in the PD Program by Teacher Educators (N = 16)

Technologies	Frequency of use												Change		
	Before						After						<i>t</i>	df	<i>p</i>
	N				M	SD	N				M	SD			
1	2	3	4	1			2	3	4						
Desktop computers	12	1	1	2	1.56	1.09	2	4	8	2	2.63	0.89	3.78	15	0.002*
Laptops	15	1	0	0	1.13	0.50	10	5	1	0	1.44	0.63	1.77	15	0.096
Audio Equipment (e.g., Radio, CD Player,)	15	1	0	0	1.13	0.50	14	1	1	0	1.19	0.54	0.32	15	0.751
Digital Photo Camera	15	1	0	0	1.13	0.50	15	0	1	0	1.13	0.50	0.00	15	1.000
Mobile Phones	14	1	1	0	1.31	0.87	11	0	2	1	1.47	0.92	0.49	14	0.634
Data Projector Systems	3	1	7	5	1.81	1.0	2	3	9	2	2.88	0.71	2.57	15	0.021*
Television	15	1	0	0	1.13	0.50	16	0	0	0	1.00	0.00	1.00	15	0.333

1 = Never, 2 = Once or twice per semester, 3 = about once every month, 4 = At least once per week

**p* < 0.05

Table 5.41 shows that most teacher educators, with a few non response items, indicated that, in addition to using data projector systems ($M = 2.81$, $SD = 0.71$), they had started to use computers in their teaching ($M = 2.63$, $SD = 0.89$) at least once per month after participating in the revised PD program. Although a positive mean change was observed in the frequency of use of the available technologies, a significant change was observed only in using computers ($[df = 15] = 3.78$, $p < 0.002$), which were the focus of the PD program.

Similarly, teacher educators were asked to rate how frequently they used learning technologies in their teaching before and after the PD program. The results are shown in Table 5.42. This table shows that the teacher educators were using some learning resources after the PD with significant changes in mean relating to the use of Microsoft Mathematics ($[df = 14] = 4.00$, $p < 0.001$) and GeoGebra ($[df = 12] = 4.39$, $p < 0.001$). Given that these were used in the exemplar material, this finding suggests that the teacher educators used the material.

Table 5. 42

Teacher Educators' Frequency of Use of Learning Technologies before and after Participating in the PD Program (N = 16)

Learning resources	Frequency of use												Change				
	Before						After										
	1	2	3	4	N	M	SD	1	2	3	4	N	M	SD	t	df	p
YouTube	14	1	0	0		1.13	0.52	5	5	4	2		2.19	1.05	3.10	14	0.008
Weblogs	15	1	0	0		1.00	0.00	13	1	1	0		1.20	0.56	1.39	13	0.189
Social Learning Communities	13	2	0	0		1.13	0.35	13	2	1	0		1.25	0.58	0.70	14	0.499
Search Engine like Google	5	2	5	4		2.50	1.21	2	3	1	9		3.13	1.19	1.66	14	0.119
Email	11	1	3	0		1.67	1.23	10	1	2	2		1.73	1.16	0.62	13	0.547
Chat Rooms	14	0	0	0		1.00	0.00	13	1	1	0		1.20	0.56	1.39	12	0.190
GeoGebra	13	0	0	0		1.00	0.00	7	6	3	0		1.75	0.77	4.39	12	0.001*
Microsoft Mathematics	13	2	0	0		1.13	0.35	4	6	5	1		2.19	0.91	4.00	14	0.001*
Spreadsheets like Excel	11	3	0	1		1.40	0.83	10	2	4	0		1.63	0.89	0.81	14	0.433
PowerPoint Slides	11	1	1	2		1.60	1.12	8	4	3	1		1.81	0.98	0.72	14	0.484

1 = Never, 2 = Once or twice per semester, 3 = about once every month, 4 = At least once per week

*Significant mean change

5.3.3. Pre-service teacher use of technology. Similarly to their teacher educators, the practices of using technologies and learning resources by pre-service teachers were also examined following the PD. Table 5.43 shows pre-service teachers' reported frequency of use of the technologies before and after their teacher educators had participated in the PD program.

Table 5.43 shows that most pre-service teachers started using some of the available technologies about once every month in their learning after the teacher educators participated in the PD program. Changes were significant for all items. These findings suggest that teacher educators were passing on their new knowledge to their students.

Following Table 5.43, the frequency of use of selected learning resources by pre-service teachers before and after their teacher educators participated in the revised PD program is shown in Table 5.44. As evident in Table 5.44, pre-service teachers had started to use learning resources in their learning after the teacher educators participated in the revised PD program. For example, a significant mean change is observed in using YouTube ($[df = 90] = 11.49, p < 0.000$) after teacher educators participated in the revised PD program. Similar significant mean changes were observed for using GeoGebra ($[df = 88] = 11.80, p < 0.000$), Microsoft Mathematics ($[df = 104] = 13.98, p < 0.000$), and Excel ($[df = 74] = 6.81, p < 0.000$) suggesting the pre-service teachers had begun to use technologies which were used by their teacher educators.

Table 5. 43

Frequency of Use of Technologies by Pre-Service Teachers before and after Teacher Educators Participated in the PD Program

Technologies	Frequency of use												Change									
	Before						After						t	df	p							
	N			M			SD			N						M			SD			
	1	2	3	4																		
Desktop computers	87	12	2	15	1.53	1.03														19.76	113	0.000**
Laptops	97	3	2	12	1.37	0.95														5.52	102	0.000**
Audio Equipment (e.g., Radio, CD Player,)	98	9	1	6	1.25	0.72														2.83	98	0.005*
Digital Photo Camera	107	3	1	6	1.05	0.32														5.15	95	0.000**
Mobile Phones	87	7	4	15	1.53	1.06														2.27	98	0.026*
Data Projector Systems	84	7	11	12	1.57	1.03														17.87	101	0.000**
Television	102	5	3	6	1.25	0.74														6.73	101	0.000**

1 = Never, 2 = Once or twice per semester, 3 = about once every month, 4 = At least once per week

* $p < 0.05$, ** $p < 0.01$

Table 5. 44

Pre-Service Teachers' Frequency of Use of Learning Resources before and after their Teacher Educators Participated in the PD Program

Learning resources	Frequency of use										Change				
	Before					After					t	df	p		
	1	2	3	4	M	SD	1	2	3	4				M	SD
YouTube	99	4	2	5	1.21	0.69	1	9	83	16	3.05	0.52	11.49	90	0.000**
Weblogs	98	2	3	6	1.24	0.75	73	29	4	2	1.40	0.65	3.01	87	0.003*
Social Learning Communities	87	6	8	10	1.37	0.97	84	13	3	7	1.47	0.83	4.89	91	0.000**
Search Engine like Google	99	4	6	4	1.24	0.71	0	4	92	13	3.08	0.39	9.40	91	0.000**
Email	97	3	5	7	1.30	0.82	66	37	2	3	1.46	0.68	4.51	90	0.000*
Chat Rooms	99	3	7	4	1.25	0.72	62	40	4	2	1.50	0.66	2.15	91	0.034*
GeoGebra	99	6	3	3	1.19	0.61	0	12	87	6	2.94	0.41	11.80	88	0.000**
Microsoft Mathematics	92	8	5	6	1.32	0.80	0	5	58	58	3.44	0.58	13.98	104	0.000**
Spreadsheets like Excel	93	11	4	4	1.28	0.70	0	13	90	7	2.95	0.42	6.810	74	0.000**
PowerPoint Slides	87	6	10	9	1.47	0.98	0	0	75	34	3.31	0.47	9.405	74	0.000**

1 = Never, 2 = Once or twice per semester, 3 = about once every month, 4 = At least once per week, * $p < 0.05$, ** $p < 0.01$

5.3.4. Classroom contexts: Teacher educators' technology integrated lessons. As explained in Chapter 4, Section 4.4.3, a series of lessons was observed by the researcher before and after the teacher educators participated in the PD program. The lessons involved using a particular ICT in the teaching of a mathematical concept. Twenty four lessons (12 before and 12 after) were observed with each having a duration of approximately 50 minutes. The completed observation results of teacher educators before participating in the revised PD program were reported in Table 5.13. Results of the teacher educators' technology integrated teaching practices after participating in the PD program are shown in Appendix P. A summary of the observation results both before and after participating in the revised PD program is provided in Table 5.45 reported using the modes scores (as defined in Chapter 4, Section 4.6.1) and an indication of whether there was a change in the mode.

Table 5. 45

Teacher Educators' STAMPK before and after Teacher Educators Participated in the PD Program Audited Using an Observation Checklist (N = 16)

STAMPK Components	Mode		Mode change
	Before	After	
TK	2	3	✓
SMK	3	3	x
SPK	2	3	✓
SPMK	2	3	✓
STPK	1	3	✓
STMK	1	3	✓
STAMPK	1	3	✓

1 = not observed, 2 = partly observed, 3 = observed

As with the results from the questionnaire (see Table 5.40), Table 5.45 shows that there were changes in the modal values for each construct of STAMPK except SMK as observed in the classroom. The mode change in STPMK, for example, indicated a shift from not observed (1) to observed (3) in classroom practice. Similar to the results found in the questionnaire of teacher educators' STAMPK constructs, the construct SMK did not show changes the teacher educators demonstrated SMK both before and after the PD program.

Both pre and post questionnaires asked teacher educators to give an example of a lesson they had taught using technology before and after participating in the PD program. This was included to determine whether or not teacher educators considered the interplay among SMK, SPK and TK. The examples provided by the four teacher educators who provided answers for the question both before and after the PD, are summarised in Table 5.46 with comparisons made between lesson examples provided before and after participation in the PD program.

Table 5.46 shows that before participating in the PD program teacher educators were unable to give examples of lessons they taught which considered technology except one teacher educator who considered Excel in teaching inferential statistics (Teacher Educator 6).

Table 5. 46

Teacher Educators' Lessons Taught Using Technology before and after Participating in the PD Program

ID	Before the PD program	After the PD program
1	I had not used any technologies because I have limited experience and skills on how to use technologies in my lessons. I cannot describe a single lesson. I taught by using projector	I used Cabri 3D in teaching Geometry lessons. The content was finding area of a circle through inscribed regular polygon. Then, as the number of sides of a regular polygon increases the area approaches to the area of the circle inscribing the polygon. I used group work as a teaching approach Content: Area of a circle $A = \pi r^2$. To show the formula derivation of the area of a circle from the area of a regular polygon $A = \frac{1}{2} n r^2 \sin \frac{360}{n}$. Increase the number sides of the polygon and observe the value of $\frac{1}{2} n \sin \frac{360}{n}$. As $n \rightarrow \infty$, $\frac{1}{2} n c = \frac{360}{n} \rightarrow \pi$ and A (polygon) $= A = \frac{1}{2} n r^2 \sin \frac{360}{n} \rightarrow A = \pi r^2$. By using Authoware, animation---> show how the polygon approaches the areas of a circle as $n \rightarrow \infty$ Content: Solving systems of linear equations; reducing matrices to row reduced echelon form; determining the transpose, inverse, determinant; size of matrices. Technology: Microsoft mathematics. Teaching Approach: Group discussion and independent work
2	I could not describe a specific lesson, which fulfils the mentioned criteria. I had never thought of adding technology in pedagogy and content (PCK)	
5	I have never used any kind of technology in teaching maths which engage pre-service teachers	
6	No, I don't have experience previously except using Excel and a simple projector to teach about inferential statistics if that counts	Content: Simple linear regression and correlation. Technology: SPSS Software. Pedagogy: I used group work. Students discussed in groups observing results from the computer screen.

After the PD program, however, nine teacher educators were able to list examples of lessons, which considered technology. Teacher Educator 16 said during the second interview:

I taught a lesson combining content, technology and pedagogical approach. The lesson was about the convergence of sequences that makes the pre-service teachers using Microsoft Mathematics to identify a given sequence is bounded, monotone and convergent. The teaching approach was independent learning at the first stage and then pair work and later discussed as a whole class. [Teacher Educator 16].

The teacher educators were also asked during the second interview if they considered the STAMPK framework while designing their technology integrated teaching. Most of them indicated that the STAMPK framework was helpful in designing lessons, but recognised that it was complex and required teacher educators' creativity to use in the classroom practically. For example, Teacher Educator 6 emphasised the importance STAMPK framework as follows:

We were often challenged to use the appropriate technology, which fits with particular content and pedagogy. The STAMPK framework had a role to think this through systematically. We used the STAMPK framework to design our lessons; however, the framework required creativity inputs. [Teacher Educator 6].

Further to the summary of the lessons in Tables 5.45 and 5.46, the following section provides descriptions of two cases of technology integrated lessons taught by two teacher educators after participating in the PD program. The lessons were selected based on their appropriateness to represent i) effective technology integrated mathematics teaching and ii) the importance of pre-requisite technological knowledge of pre-service teachers to when using technology in teaching. In each case, a comparison is made with the same teacher educator's

technology integrated teaching observed before participating in the PD program. The comparisons were made based on observation results and interviews with pre-service teachers who attended the lessons and the teacher educators who taught them. The two lessons were taught to two different groups of pre-service teachers (pre-service teachers finishing their first year and pre-service teachers finishing their second year respectively). In each case, the lesson was observed 3 ½ months after the first lessons were observed.

5.3.4.1. Case 1: A teacher educator using Microsoft Mathematics. This case, reported in Getenet and Beswick (2014), consisted of two video recorded lessons and interview data provided by the mathematics Teacher Educator 1 and three primary school mathematics pre-service teachers who were in the class of learners. The pre-service teachers were finishing their first year in the program. They were enrolled in Basic Mathematics II, the content of which includes graphs of logarithmic functions. The teacher educator who taught these lessons totalling 2 hours was selected based on his effectiveness in using Microsoft Mathematics after participating in the PD program. Once the pre-service teachers were familiar with the menus and toolbars of the software, they learned how to graph logarithmic functions. They were then asked to work in groups of three or four to illustrate properties of graphs of logarithmic functions. The questions shown in Figure 5.3 were provided to guide their work.

- 1) Sketch the graphs of the following logarithmic functions:
 - a. $f(x) = \log_2 x$
 - b. $f(x) = \log_5 x$
 - c. $f(x) = \log_{\frac{7}{2}} x$
 - d. $f(x) = \log_{\frac{2}{3}} x$
 - e. $f(x) = \log_{\frac{1}{2}} x$
- 2) Describe the shapes of the graphs when $b > 1$, and $0 < b < 1$
- 3) Describe properties of the graphs listed in question 1
 - a. Common properties
 - b. Describe the graphs when $x > 1$, and $0 < x < 1$, $x = 1$

Figure 5. 3. Questions explored using Microsoft Mathematics (Getenet & Beswick, 2014, p. 155).

After the two lessons were completed, the teacher educator was asked for his views of the lessons he taught with technology, in particular Microsoft Mathematics, and about his previous teaching of graphs of logarithmic functions. Pre-service teachers were asked for their opinions about the technology integrated lessons.

The teacher educator described two methods of sketching graphs of logarithmic functions. The first involved taking a simple logarithmic statement, switching it around to the corresponding exponential statement, and then figuring out the x -value needed for that exponent (y -value). The most frequently used method has been the T-chart method, which can be used by taking powers of the base of the function as x -values and finding the corresponding y -values. For example, to draw the graph $f(x) = \log_2(x)$, pre-service teachers could list some values of x and y on the T-chart and then sketch the graph by connecting points as shown in Figure 5.4. However, the teacher educator acknowledged that this method is challenging for comparing multiple

graphs on the same axes such as to identify which graphs approach the y axis when $x > 1$, and $0 < x < 1$.

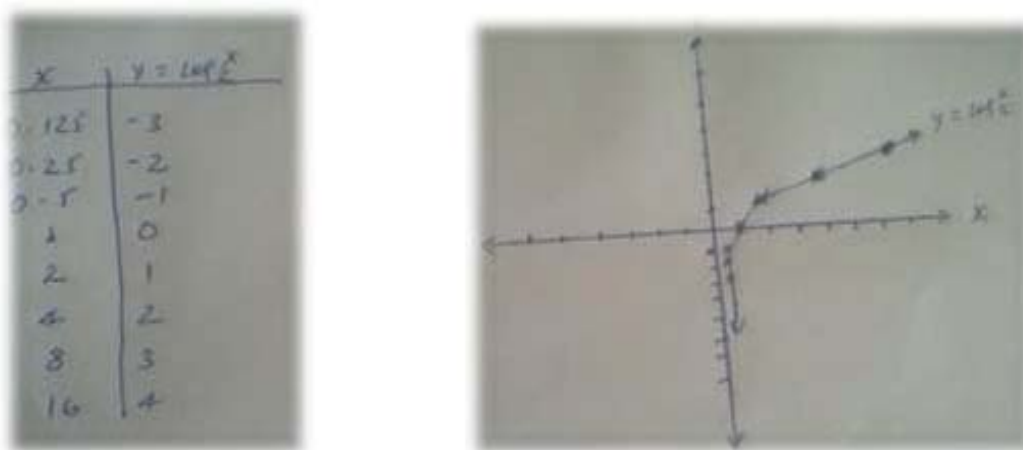


Figure 5. 4. T-chart and graph of $f(x) = \log_2(x)$ (Getenet & Beswick, 2014, p. 156).

Using Microsoft Mathematics, however, each group of pre-service teachers was readily able to draw multiple graphs of logarithmic functions, with distinct colours, and on the same axes, as illustrated in Figure 5.5. In using Microsoft Mathematics, pre-service teachers were required to write the equation in the ‘writing box’ and then to click on the icon ‘graph’ to find the graph of the corresponding equation. During the interview, Pre-service Teacher 1 pointed to the effect of using the software on learners’ engagement while admitting incomplete understanding of what was happening. She said:

The software helped me to easily sketch each graph on the same x-y axis with distinct colours; however, I do not know clearly how it happened. [Pre-service Teacher 1].

This comment suggested that she had some misunderstanding on the concept.

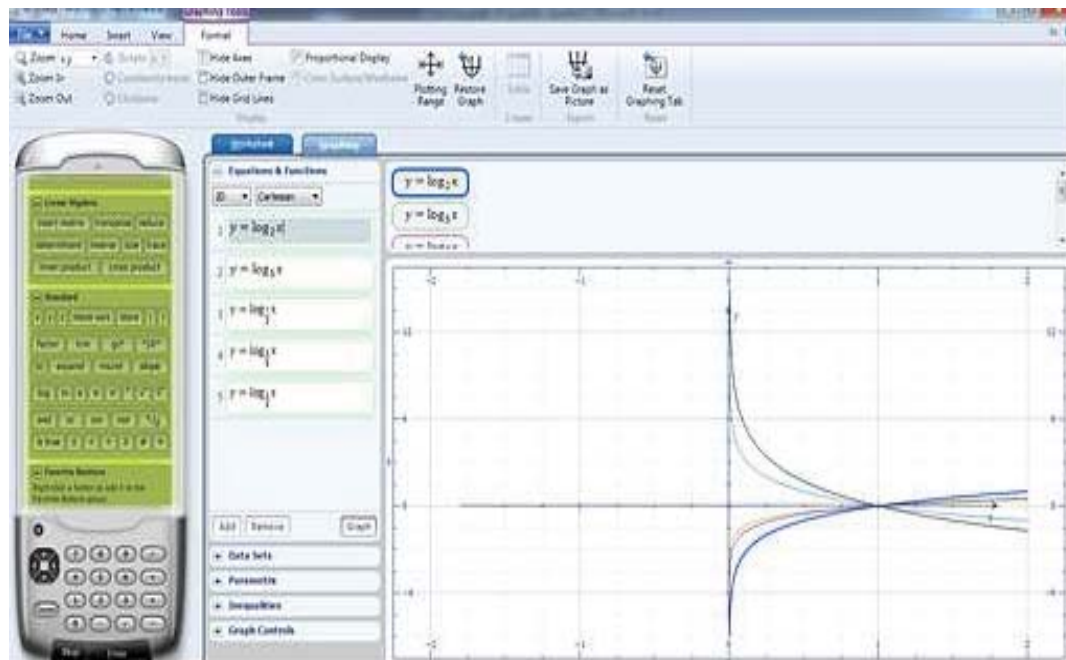


Figure 5. 5 . Graphs of some logarithmic functions created in the Microsoft Mathematics.

Using MS Microsoft Mathematics, the pre-service teachers were able to describe the shapes of multiple graphs with a general equation without sketching each graph. They were able to identify each graph's properties by changing the value of b between $b > 1$, and $0 < b < 1$ using the 'animate' feature of Microsoft Mathematics generating a movie of different graphs as b changed. For example, pre-service teachers observed and described the shapes of logarithmic functions for values of b between 0 and 2 using the animate icon. Pre-service teachers appeared to recognise and appreciate the shape change when b becomes greater than 1. During the interview, Pre-service Teacher 3 expressed his interest in these animations.

I liked the role of 'animate' to clearly see the shape of the graphs of multiple logarithmic functions as the base b varies without sketching samples of multiple graphs. [Pre-service teacher 3].

Similarly, Pre-service teacher 1 indicated the impression as b crossed 1 as:

By using 'animate' function I was able to understand the graph approached positive y-axis as $b < 1$, whereas, it approached negative y-axis as $b > 1$. [Pre-service teacher 1].

Similarly, pre-service teachers readily identified that all logarithmic functions have the same general shape, with their graphs varying depending on the base and coefficients in the equation using Microsoft Mathematics. Further, pre-service teachers pointed out that using Microsoft Mathematics was supportive in helping them to identify and describe the common properties of the logarithmic function when, $b > 1$, and $0 < b < 1$, such as the fact that all graphs of logarithmic functions have a vertical asymptote at $x = 0$, and cross the x -axis at $x = 1$. When interviewed, Pre-service Teacher 2 described the usefulness of Microsoft Mathematics in this regard, as follows:

I liked the software, which helped to graph all logarithmic functions on the same x-y axis with different colours. This helped me to list and understand the common properties of logarithmic function when the base, b , varies. [Pre-service teacher 2].

One group of pre-service teachers identified the properties of the graphs by using 'Trace' function. The 'Trace' function varies the values of x and y continuously for a given base, b , as x moves through a specified range of values. In this case pre-service teachers identified the values of y as x moved between $x > 1$, $0 < x < 1$.

Finally, the lessons were audited using an observation checklist rubric. Table 5.47 provides a summary of the results in the form of modal scores in each construct of STAMPK.

Table 5. 47

The Teacher Educator's STAMPK as Observed in the Classroom

STAMPK component	Mode	Description
TK	3	The teacher educator used Microsoft Mathematics efficiently
SMK	3	The teacher educator demonstrated the specialist knowledge to teach the content
SPK	3	The group work was efficient in engaging pre-service teachers during the lesson
SPMK	3	The topic was appropriate to be taught in groups involving peer discussion
STPK	3	The technology selected was effective in stimulating pre-service teachers' peer discussion
STMK	3	The technology was appropriate to teach the graph of logarithmic function
STAMPK	3	The lesson was delivered effectively and in harmony with the selected technology (Microsoft Mathematics) and pedagogy (involving group work and peer discussions)

1 = not observed, 2 = partly observed, 3 = observed

As Table 5.47 shows, the technology selected was used effectively teaching about the graphs of logarithmic functions. The technology facilitated pre-service teachers' group and pair discussions. This particular lesson was more engaging than the lesson observed before the teacher educators participated in the PD program (see Table 5. 14). Pre-service teacher engagement was evidenced from the teacher educators' STPK in Table 5.47 on which the technology selected was effective in prompting the pre-service teachers opportunities to discuss the mathematics with their peers. The comparison of this teacher educator teaching prior and

after the PD program is shown in Table 5.48 based on his modal scores in each construct of STAMPK.

Table 5. 48

Case 1: The Teacher Educator's Lesson as Observed before and after Participating in the PD Program

STAMPK Components	Mode		Change
	Before	After	
TK	2	3	✓
SMK	3	3	x
SPK	2	3	✓
SPMK	1	3	✓
STPK	1	3	✓
STMK	3	3	x
STAMPK	1	3	✓

1 = not observed, 2 = partly observed, 3 = observed

As shown in Table 5.14 in Section 5.1.1 before participating in the PD program, the teacher educator was challenged to select and use an appropriate technology to teach increasing and decreasing functions. After participating in the revised PD program, however, the teacher educator was able to teach graphing of logarithmic functions with the application of Microsoft Mathematics. The technology supported learners to engage in the lesson. This was evident from the fact that the values of STPK, STMK, and STAMPK moved from not observed to observed. Not only did the teacher educator use technology, he also moved from a teacher centred approach lecture approach to a more student centred pedagogy using group and pair discussions. This change was supported by the software used.

The pre-service teachers expressed a range of perspectives on the use of Microsoft Mathematics in learning graphs of logarithmic functions. One had mixed feelings about using Microsoft Mathematics, expressing a preference to work initially without using any technology and then later use the Microsoft Mathematics. Although she recognised the significance of technology, she tended to believe that graphs of logarithmic function should be first taught without technology then later by the Microsoft Mathematics. This was the same pre-service teacher who had admitted being unsure of how Microsoft Mathematics produced the graphs. Another explained the advantage of Microsoft Mathematics compared with his previous lessons. He said:

At the first glance, the graph of the logarithmic function can easily be mistaken for that of the square root function when sketching manually. Both the square root and logarithmic functions have a domain limited to x values greater than 0. However, the logarithmic function has a vertical asymptote descending towards negative ∞ as x approaches 0, whereas the square root reaches a minimum y value of 0. This difference was demonstrated clearly by using Microsoft Mathematics. [Pre-service teacher 3].

Pre-service Teacher 2 indicated that Microsoft Mathematics helped him to externalise his reasoning, work at his own pace, and manage the complexity of the task. He said:

Microsoft Mathematics complements my learning of graphs of logarithmic function by helping to visualise, understand, and animate to identify their properties. ... I liked the process as I was engaged and discussed with peers throughout the process and it was a different approach. [Pre-service teacher 2].

The teacher educator described the role of Microsoft Mathematics as follows:

The software was vital and complements pre-service teachers' ability to discuss the problem and engaging them in a small guided group.... The discussion within small groups was thought provoking as they were engaged through manipulating the computer. I liked Microsoft Mathematics as it complements my efforts by helping pre-service teachers to visualise graphs of logarithmic functions as well as provoked active engagement of pre-service teachers. [Teacher Educator 1].

5.3.4.2. Case 2: A teacher educator using GeoGebra. This case comprised a 1.5 hour video recorded lesson and interview data provided by a teacher educator and two pre-service teachers who were in the class of learners. They were enrolled in a plane geometry unit and were finishing their second year in the program. The contents of the unit included the area of a circle and estimating the value of π . All 31 pre-service teachers in the class participated in the observation part of the study. The objective of this lesson was to approximate the area of a unit circle (π) in terms of a regular polygon inscribed in the unit circle.

Similar to the first case, once the pre-service teachers were familiar with the menus and toolbars of GeoGebra, they learned how to find the area of a circle and a regular polygon. Pre-service teachers using GeoGebra readily understood and described the value of π and the area of a circle in terms of a regular polygon inscribed in a circle. They were then asked to work in groups of three or four. The questions shown in Figure 5.6 were provided to guide their work

Compare the areas of regular polygon inscribed in a circle of radius 1 cm and the circle itself. The formula for areas of a regular polygon is

$$A(\text{Poloygon}) = \frac{n \times \text{side} \times \text{apothem}}{2} = \frac{\text{perimeter} \times \text{apothem}}{2} \text{ and } A(c) = \pi r^2, \text{ where}$$

apothem of a regular polygon is defined as a line segment from the canter to the midpoint of one of its sides.

1. What do you observe as n increases from 3 to 30 in the shape of the polygon?
2. What will be the relationship between the area of the regular polygon and the unit circle as n increase?
3. Compare the radius of the circle and the apothem and approximate value of π .

Figure 5. 6. Questions explored using GeoGebra.

At the beginning of the lesson, the teacher educator introduced how to find the area and perimeter and apothem of the first three regular polygons using GeoGebra projected on a screen and recording the results in a table as indicated in Table 5.49.

Table 5. 49

Area of Selected Regular Polygons Inscribed in a Circle Using GeoGebra

Polygon	Number Of Sides	Estimated Area (cm ²)	Perimeter (cm)	Apothem (cm)
Triangle	3	1.29903	5.20	0.71
Square	4	2.00000	5.74	
Pentagon	5	2.37764	5.90	
n				

Furthermore, the teacher educator sketched an inscribed square in a unit circle with its corresponding area as indicated in Figure 5.7

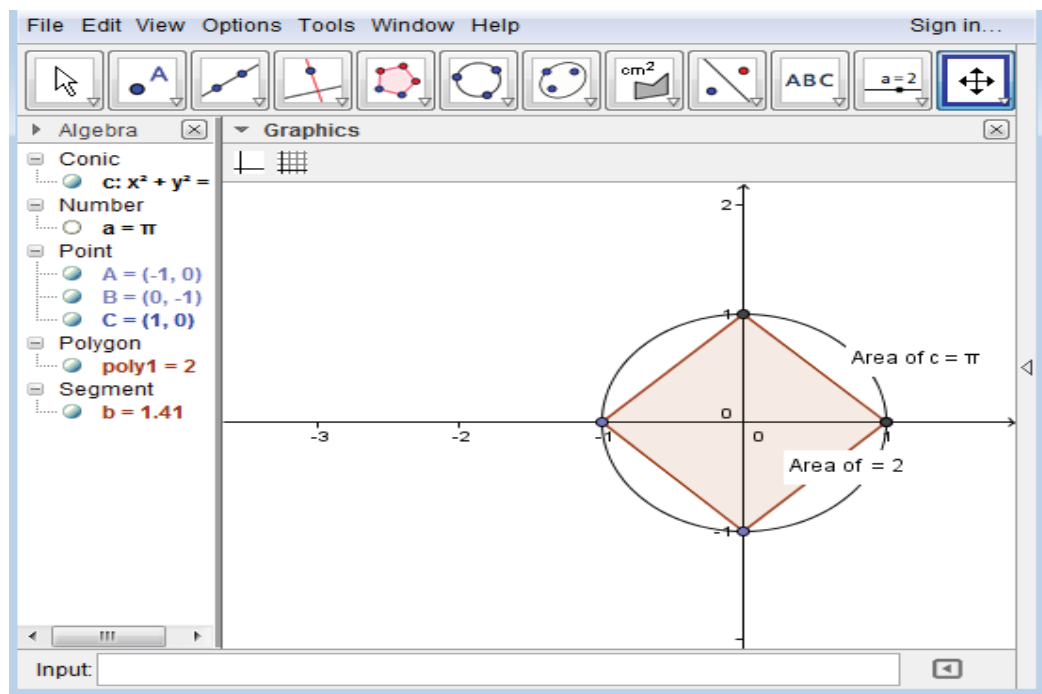


Figure 5. 7. Area of a circle and inscribed regular polygon using GeoGebra.

The pre-service teachers used the format indicated in Table 5.49 and compared the area of the regular polygon with the area of the circle as n increased. Pre-service teachers sketched the circle and then the inscribed polygon varying the number of sides using GeoGebra. They found the area of the circle and of the inscribed polygon and the results were recorded in a table like that shown in Table 5.49. There was active discussion in each group, especially when comparing the area of the circle and the inscribed polygon. During the second interview, one of the two pre-service teachers commented about this lesson as follows:

The lesson on finding in the area of a circle with the help of inscribed regular polygon using GeoGebra was engaging and supported to estimate the value of π . We know how to find the area of regular polygon when the perimeter and the apothem are given. [Pre-service teacher 4].

The observation showed that most pre-service teachers found it challenging to use the software to sketch an inscribed regular polygon with n sides in a unit circle. Groups of pre-service teachers were comparing the area of a circle with that of the inscribed regular polygon regardless of the length of the radius of the circle. This occurred due to the difficulty of using GeoGebra effectively and efficiently. During the one to one interview after the PD program, the difficulty of using GeoGebra while learning the areas of the circle was cited by Pre-service teacher 6. He said:

Rather than directly using a particular technology for teaching, it could be wise to first let learners practice on the technology and familiar with the technology. It takes most of our time, for example, in sketching inscribed regular polygon in a unit circle using GeoGebra.

[Pre-service teacher 6].

The pre-service teachers concluded that the area approached π as n increases. For $n = 3$, the area is 1.2990. For $n = 200$, the area is 3.1411. As the value of n continued to increase, the area of the inscribed polygon approached the area of the unit circle, which is π . Inscribing regular polygons in the unit circle estimated the value of π , and therefore using these methods will generate areas that approach π .

The pre-service teachers were guided actively through the process to find the area of the regular triangle first, following the steps, so that they could replicate the process. During the discussion, the teacher educator emphasised that increasing n causes the regular polygons to become more “circle like” which is why their areas approach the area of the unit circle, known to be π . Most pre-service teachers, however, were unable to identify the value of π as they were not efficient in sketching the inscribed regular polygons in a unit circle.

One of the challenges faced by pre-service teachers was in creating an inscribed polygon and using the slider r that determined the radius of the circle. Most pre-service teacher groups were unable to create an inscribed polygon with varied number of sides within a unit circle. This lead to difficulty in finding the value of π .

In addition to describing the context of the lessons in the classroom, the lesson was evaluated using the observation checklist. The summary of the observation results is shown in Table 5.50 with modal scores for each STAMPK construct.

Table 5. 50

Lesson Evaluation Using Observation Checklist

STAMPK component	Mode	Description
TK	2	The technology selected was appropriate and the teacher educator used the technology efficiently.
SMK	3	The teacher educator was confident while explaining the content.
SPK	3	Pre-service teachers were grouped for discussion and the teacher educator was moving around helping each group
SPMK	3	The group work supported learners to discuss concepts and come up with solutions
STPK	3	The technology supported learners to collaborate and hence supported the group work discussion
STMK	3	The technology was appropriate to teach the area of the circle based on inscribed regular polygon and to estimate the value of π .
STAMPK	3	Although some pre-service teachers were challenged in using GeoGebra to estimate the value of π , the technology facilitated the group work discussion to estimate the area of the unit circle

1 = not observed, 2 = partly observed, 3 = observed

As Table 5.50 shows, the teacher educator was observed appropriately selecting a technology, which fitted with the pedagogy and the content selected to engage the learners. The technology supported group discussion to develop understanding of the area of a circle and estimate the value of π . A few pre-service teachers were unable to use the software efficiently and so GeoGebra did not support them to estimate the value of π . The same teacher educator used an overhead projector to teach the concept “Applications of Limit” before participating in the PD program. During that lesson, the technology was used only to display the subject matter. The teacher educator did most of the activities while the pre-service teachers took notes. The use of GeoGebra helped the teacher educator shift to a more student centred approach.

5.3.5. Teacher educators’ and pre-service teachers’ experience with technology integrated lessons. Following the PD, aspects of teacher educators and pre-service teachers’ views and their recollection of an experience with technology integrated teaching were obtained by using questionnaires, observations and interviews. These experiences and views are presented in this section in relation to two themes: aspects of technology integrated lessons that were most liked and those that were not liked.

During the post PD individual interviews, the teacher educators were asked to share their experiences of teaching technology integrated lessons after the PD program. The question was “What did you think of the lessons you taught?” Further questions also guided the interviews (see Appendix I). The reflections of the teacher educators provided in the interviews are summarised in the following section categorised as aspects they liked and the aspects they did not like. Table 5.51 shows the teacher educator feedback.

Table 5. 51

Reasons for which Teacher Educators Liked and Disliked Technology Integrated Lessons

	Reasons	Teacher educator
Liking	It engages learners because learners were doing activities by themselves and at their own pace	3
	The lesson was interactive and learners were happy, as it is a different approach from the usual	4
	Though it requires preparation in advance, the process will give more authority to the learners than the teacher educator.	1
	Gives the opportunity to try our skill in teaching a particular mathematics concept with a different approach	5
	It creates the opportunity for pre-service teachers to discuss with colleagues	2
Disliking	Preparation of the lesson required ample time as it is not the one I have practiced before	6
	They did not like lessons, which involved software unfamiliar with pre-service teachers	1

Results from post PD questionnaires, and interviews as well as observation sessions indicated that overall pre-service teachers were positive about most of the technology integrated lessons that they had attended. The aspects pre-service teachers most liked and disliked are summarised in Table 5.52.

Table 5. 52
Reasons for which Pre-Service Teachers Liked or Disliked Technology Integrated Lessons

Reasons	Pre-service teacher
I liked the opportunity to be involved in the learning process by my own pace and time	8
I was happy the process encourages learning by doing as I like to learn by doing	4
The process simplifies concepts. For example, while learning the graphs of logarithmic function using Microsoft Mathematics, the process supported us to graph all logarithmic functions on the same x-y axis with different colours	7
I liked lessons, which included motions. For example, while learning logarithmic functions, the software supported to show the shapes of graphs logarithmic functions as the base b varies without the need to sketch multiple graphs	5
I liked the way I was involved in the learning process rather than listening to teacher educator's lecture	3
The combined lesson of overhead projector and learning with computers was more engaging and thought provoking.	1
Some of the lessons covered a wide range of contents within a short period in a clear and explicit way	2
I can say I have experienced not only learning with technology, but also how to teach mathematics using technology	10
There was more advanced software (e.g., AutoCAD) that we were not familiar with to play around. Lessons involving software, which we were not familiar, were boring. It took time to play around the software than learning the concept	4
We did not enjoy lesson which did not show the process, but only products	7
I did not enjoy the lesson, which was only overhead based. I enjoyed the lessons, which were engaging and participating in the process	9

In summary, the pre-service teachers enjoyed the technology integrated lessons which involved them in classroom activities and gave them an opportunity to play around with technologies. They were, however, unhappy with lessons that were dominated by the teacher educator and lessons involving technologies that demanded more advanced technical skills than they had.

5.3.6. Effectiveness of the PD program. At the conclusion of the PD program, teacher educators were asked to evaluate the effectiveness of the PD program. This was done during the final workshop, a focus group discussion, and interviews with individual teacher educators. The findings revealed particular aspects of the PD program that the teacher educators found most engaging and effective. They were positive about the PD program guidelines, including the formation of teams, the informal PD program structure, the use of exemplar material and their involvement in a specialised PD program. The reflections of teacher educators in relation to each of these aspects are illustrated below.

5.3.6.1. Formation of teams. During the interview and final workshop, the teacher educators perceived the formation of teams as one of the most effective aspects of the PD program. They found team formation a useful strategy for collaboration that allowed them to participate in the PD program on their own schedule. During the interview, a teacher educator indicated this advantage as follows:

The formation of the team based on our office arrangement facilitated sharing of experience and collaboration between colleagues in an effective way. [Teacher Educator 6].

The reflections during the final workshop produced similar results. For example:

The formation of the team based on the teacher educators, office arrangement facilitated peer discussion and collaboration. We were easily discussing when the issue comes arises on technology integrated teaching. [Teacher Educator 4].

There were some limitations, however, such as the restriction formation of team based on a teacher educators' office arrangement placed on collaboration with other teacher educators:

Formation of smaller teams had multiple advantages during the PD program process; however, it sometimes acts as a fence to create opportunity to discuss with other teacher educators who are not in a similar team. We often instantly considered we should only discuss within our own team. [Teacher Educator 5].

The comment offered by Teacher Educator 5 suggested that the formation of smaller teams should create an opportunity to discuss issues between teams rather than be limiting discussion to within a team.

5.3.6.2. Use of exemplar material. The exemplar material was considered one of the elements of the PD program that contributed to its effectiveness. Teacher educators explained the contributions of the exemplar material in supporting their efforts to design technology integrated lessons. During the final workshop Teacher Educator 15 explained how the exemplar material supported her:

The exemplar material supported me to design lessons. Particularly while thinking which technology should be selected to fit with the mathematical concept I am going to teach and the pedagogy I am going to use. [Teacher Educator 15].

This comment suggested that the exemplar material helped this teacher educator to consider not only the technology but also the pedagogy. Furthermore, teacher educators indicated

the importance of the exemplar material in the PD program process, particularly for those who had never experienced technology integrated teaching before. Teacher Educator 8 described it, during the focus group discussion, as follows:

The exemplar material can be a good reference and support for those who had no previous experience in technology integrated teaching. It was a point of reference in designing lessons. [Teacher Educator 8].

This comment suggests that the exemplar material was a useful resource for generating initial ideas around which to design technology integrated lessons.

5.3.6.3. Emphasis on informal PD program. As discussed in Section 5.2.2, the teacher educators were not in favour of PD programs characterised by large group sessions. Instead, they preferred PD programs structured around their availability and that fitted with their own schedules. Three themes emerged during the individual interviews, focus group discussion, and final workshop reflection about the advantages of an informal PD program:

- It did not require the presence of all teacher educators at the same time,
- It facilitated easy discussion and collaboration with colleagues, and
- It created a feeling of continuous PD program for participant teacher educators.

For example, Teacher Educator 10 indicated the advantages of informal PD program to fit with his schedule. He said:

I can discuss my technology integrated teaching experiences with fellow teacher educators and ICT coordinators when I need. I do not need to follow a certain schedule blocked in PD program. [Teacher Educators 10].

During the workshop, teacher educators indicated the importance of the informal PD program in creating a feeling of continuous PD program. During the final workshop, Teacher Educator 12 said:

If the PD program was structured in the way with the sense of togetherness with a blocked period of time, the issue of the PD, including peer discussion and collaboration will end at the end date. The introduction of informal PD, however, creates a feeling on participants' as if we are still in the PD program process. [Teacher Educator 12].

Teacher Educator 6 supported Teacher Educator 12 in this. He said:

Informal PD program has no strict end date. We do not know really, when the PD program will stop. We often discuss on the issue when appropriate. [Teacher Educator 6].

The findings in this section showed the importance of participating in a PD program focused on the effective use of technology in their teaching of mathematics, characterised by team formation, supported by exemplar material, and other informal support arrangements such as provided by the ICT coordinator. These arrangements also seemed to encourage sustainability as suggested by Teacher Educator 6.

5.4. Chapter Summary

This chapter has presented the findings of the study. It was organised in three sections. The first section, Section 5.1, introduced the importance of context analysis, which was used to design the first Prototype I PD program. In the context analysis, two major contexts were considered: learners' context (teacher educators' and pre-service teachers'), and the learning context (need assessment and analysis of the learning environment). The findings of the

contextual analysis were consistent with the findings in the literature and facilitated the design of the first prototype PD program.

The second section, Section 5.2 introduced the design and subsequent revision and redesign of the PD program. This section illustrated the revision and redesign process of Prototype I in collaboration with teacher educators, pre-service teachers and mathematics education professors. The suggested PD program guidelines were formation of teams, support from ICT coordinators, and informal PD program arrangements. The findings in Section 5.2 facilitated the full implementation the PD program at the later stage of the study.

Section 5.3 presented the results found after teacher educators had participated in the revised PD program. The findings in this section showed that teacher educators started using the available technologies in their teaching of mathematics and overall pre-service teachers enjoyed technology integrated mathematics lessons. The findings revealed that teacher educators' participation in the PD program facilitated their use of available technologies in their teaching of mathematics. Teacher educators considered using computers and software (for example, Microsoft Mathematics, GeoGebra) in their teaching of mathematics and highlighted the importance of participating in the revised PD program characterised by team formation, supported by exemplar material, and informal setup, to use effectively technology in their teaching of mathematics.

Based on the results presented in Chapter 5, the following chapter, Chapter 6, will provide an analytical discussion of the major findings. The discussion will make links with the literature reviewed in Chapter 3.

Chapter 6 Discussion

Chapter 5 presented the results of the analyses of the quantitative and qualitative data collected throughout the three phases of the study. These included the results of the contextual analysis used as the basis for the design of the Professional Development (PD) program and the formative evaluation and refinement of the PD program. The impact of the PD program on the teacher educators' technology integrated mathematics teaching practices and pre-service teachers' learning was also presented. This chapter, Chapter 6, discusses the results in relation to the literature reviewed in Chapter 3. This chapter is organised in four sections. The first section, Section 6.1 discusses the teacher educators' perceptions of their Specialised Technological and Mathematics Pedagogical Knowledge (STAMPK) and their technology integrated mathematics teaching practices, both before and after participating in the PD program. Section 6.2 discusses the factors which influenced teacher educators to integrate technology in their teaching of mathematics. The third section, Section 6.3, addresses the characteristics of an effective PD program to integrate technology in the teaching of mathematics, and finally Section 6.4 discusses the perceptions of teacher educators and pre-service teachers about technology integrated mathematics lessons.

6.1. Competencies of Teacher Educators to Integrate Technology in Teaching

One of the central parts of the study was to investigate the teacher educators' perceived STAMPK and their technology integrated mathematics teaching practices before and after participating in the PD program. The teacher educators reported greater perceived knowledge in most of STAMPK items after participating in the revised PD program compared to before their participation in the PD program. Similarly, the teacher educators demonstrated more effective

classroom practices in using technology to teach mathematics lessons after participating in the revised PD program. The results of their perceived knowledge on STAMPK and their technology integrated teaching practices were presented in Chapter 5, Sections 5.1.1, 5.3.1 and 5.3.2 are discussed in detail in the section that follows.

6.1.1. The teacher educators' perceived STAMPK. As discussed in Chapter 3, Section 3.3, the importance of technological pedagogical content knowledge, reconceptualised as STAMPK for this study, for effective use of ICT in teaching has been recognised (e.g., Harris, Mishra, & Koehler, 2009; Loughran & Berry, 2005; Mishra & Koehler, 2006; Niess, 2005; Polly, 2011). Loughran and Berry (2005) showed that such knowledge supports teacher educators to be effective in teaching technology integrated lessons and to model the appropriate pedagogical use of technologies for their students. The results from the initial questionnaire, however, indicated that the teacher educators did not have a high regard for their knowledge of technology (TK), Specialised Technological Mathematics Knowledge (STMK), Specialised Technological Pedagogical knowledge (STPK) and STAMPK before participating in the PD program (see Tables 5.5, 5.9, 5.10 and 5.11). It is likely that teacher educators' low regard for their TK had influenced their perceived STMK, STPK and STAMPK since these all depend upon TK. This result is consistent with the argument of Koehler, Mishra, and Yahya (2007) that TK, which includes skills to properly use a particular technology, is important for selecting appropriate pedagogy for the particular content to be taught. Although the teacher educators had a low perception of their TK, they reported having opportunities to work with technology. Such opportunities are a necessary pre-condition for developing successful technology integrated teaching practices, as sound TK is an asset to integrate the ICT in teaching (Chee et al., 2005).

Similarly, the teacher educators indicated that they thought themselves proficient in most of the items of Technology Proficiency Self Assessment (TPSA) questions in their daily activities (see Table 5.4). They were, however, unsure about using particular software applications such as GeoGebra for teaching mathematics or applications, which required interactive skills (see Items 8, 12, 13, 14, 17, and 20, in Table 5.4 in Chapter 5, Section 5.1.1). As Chee et al. (2005) showed, success in integrating technology in mathematics lessons is not only dependent upon knowledge of the software that is used by mathematics teachers for their personal use, but technology technical skills related are equally important for proper implementation of technology in teaching. Studies have shown that having the knowledge about the applications of various technologies is a facilitative factor to use ICT in teaching effectively (e.g., Drent & Meelissen, 2008; Mishra & Koehler, 2006). A study conducted in Sub Saharan African countries also indicated that having the technical knowledge of technologies is an important contribution to effective use of technology in teaching (Hennessy, Harrison, & Wamakote, 2010). With reference to the findings of this study, the teacher educators who participated in the PD program had preliminary technology knowledge and used technology in their teaching.

Unlike TK, STPK, STMK and STAMPK, the teacher educators had relatively high perceived competency in Specialised Mathematics Knowledge (SMK), Specialised Pedagogical Knowledge (SPK), and Specialised Pedagogical Mathematics Knowledge (SPMK) (see Tables 5.6, 5.7 and 5.8). These higher perceived competencies constituted favourable conditions for the development of effective technology integrated mathematics teaching. Shulman (1986) made a similar point. He argued that pedagogy and content knowledge are essential for teachers to deliver the required learning outcomes in teaching. Particularly, teachers' creative use of a

particular pedagogy to deliver content is vital for effective teaching. Having the SMK, SPK and SPMK was therefore, helpful in enabling the teacher educators to interpret and transform subject matter knowledge in the context of facilitating learning. This notion has remained central to elaborations of Shulman's notion of PCK specifically for mathematics teaching (e.g., Ball, Thames & Phelps, 2008; Park et al., 2011; Park & Oliver, 2008).

The initial results of the study showed that it was likely that the teacher educators could be supported through appropriate PD programs to acquire the knowledge needed to integrate technology in their teaching effectively as suggested by Harris et al.(2009), Mishra and Koehler (2006), and Niess (2005). The PD program, which was described in Section 5.2.1, influenced the teacher educators to have more positive perceptions of themselves in relation to each of the knowledge construct constituting to STAMPK, for which they perceived themselves to have little knowledge prior to their participation in the PD program. In particular, nine of the fifteen teacher educators perceived increases in their knowledge of STPK, STMK and STAMPK (see Tables 5.33 to 5.39 for detail). The changes in STPK, STMK, and STAMPK were significant with medium to large effect sizes (see Table 5.40). Similar to this finding, other studies have shown that PD programs based on such characteristics can support fundamental changes in teachers' effective pedagogy and appropriate skills to use ICT in teaching (Kalogiannakis, 2010; Schibeci et al., 2008). Consistent with their responses to the questionnaire results, the teacher educators' demonstrated improved practice of their STMK and STAMPK during the classroom observation that followed the PD program (discussed in detail in Section 6.1.2).

The knowledge types SPK, SMK and SPMK that did not involve technological knowledge, did not change. This could be because the teacher educators already perceived themselves to

have sufficient knowledge of these constructs before participating in the PD program (see Table 5.40). They had participated in the Higher Diploma Program, which ran over for one academic year (see Chapter 2, Section 2.5) and targeted teacher educators' competence in learning and teaching methods, assessment methods and key elements of the roles required of teacher educators' effective teaching (Teacher Education System Overhaul [TESO], 2003).

The teacher educators considered the STAMPK framework when designing their technology integrated teaching after participating in the PD program. Ten of them indicated that the STAMPK framework was helpful in designing lessons while acknowledging its complexity. The STAMPK framework appeared to facilitate the systematic design of technology integrated lessons. Earlier studies have demonstrated the potential of a knowledge framework to guide teachers' pedagogy as they teach specific content using ICT (Jimoyiannis, 2010), and resolve difficulties with technology integration (e.g., Koehler & Mishra, 2009; Niess et al., 2009). The teacher educators were unaware of the STAMPK framework at the beginning of this study and a theoretical workshop and discussion session with colleagues about the STAMPK framework as a pre-cursor to the PD program was imperative to developing an understanding how the teacher educators could integrate technology with appropriate pedagogy and specific content.

Overall, although teacher educators had a low regard for their knowledge of STAMPK (i.e., constructs of STAMPK included TK) before participating in the PD program, they showed a significant increase after participating in the PD program. It appeared that the teacher educators' perceived improvement in these knowledge types was associated with positive change in their effective technology integrated mathematics teaching (see Section 5.3.3). It is apposite to mention that the importance of having integrated knowledge of technology, pedagogy and

content for effective technology integrated teaching was reported in various studies. For example, Blömeke, Suhl and Kaiser (2011); and Schmidt et al. (2008) showed the professional competencies including knowledge of content, and particular pedagogy (e.g., Mathematics pedagogy) as well as general knowledge of pedagogy is important for teaching. Blömeke, Suhl and Kaiser (2011) and Schmidt et al. (2008) further showed that integrated knowledge of ICT with content and pedagogy is equally important to the effectiveness of teaching with ICT. Along with the above studies, Harris et al. (2009), Mishra, Koehler (2006), Niess (2005) and Polly (2011), advocated the importance of technological pedagogical content knowledge for successful use of technology for effective teaching in the classroom. In addition, Koehler et al. (2007) showed that good teaching with technology requires understanding of mutually reinforcing relationships between all three elements taken together to develop appropriately and context specific approach. Chee et al. (2005), Jimoyiannis (2010) and Mishra and Koehler (2006) suggested such gaps could be enhanced by PD program initiatives focusing on pedagogy, content and technological aspects and their interplay. Studies (e.g., Mishra & Koehler, 2006; Niess, 2005) have further reaffirmed that meaningful teaching with technology occurs when technology, pedagogy and content knowledge are connected in a classroom practice and treated in a PD program. Accordingly, the teacher educators' systematic use of the STAMPK framework in this study, particularly its adaptation to be used in the context of mathematics teaching, and their improved perception of their competency in relation to each STAMPK construct had significantly improved their use of technology to teach mathematics effectively. Their classroom practices are discussed in Section 6.1.2 below.

6.1.2. The teacher educators' technology integrated mathematics teaching

practices. The teacher educators' technology integrated teaching practices were studied from three different but related angles. Firstly, the teacher educators were asked to describe an example of a lesson they had taught involving technology. Secondly, they were asked how frequently they had used the available technologies in their teaching of mathematics, and thirdly, they were observed teaching technology integrated mathematics lessons. In the three situations, teacher educators evidenced improved practices after their participation in the PD program. Each is discussed as follows.

In the questionnaires administered prior to participating in the PD program, only Teacher Educator 6 was able to give examples of lessons he taught which involved the use of technology. Teacher Educator 6 described having used Excel in teaching inferential statistics before participating in the PD program. After their participation in the PD program, however, all of the teacher educators were able to describe lessons that used technology to support their pedagogy (For examples of lesson provided by the teacher educators, see Table 5.46). For example, Teacher Educator 2 explained his use of Microsoft Mathematics to teach about simplifying matrices to show reduced echelon. He used the technology to increase learners' collaboration and participation. The results showed that the teacher educators started to use technology in their teaching of mathematics more often after participating in the PD program than prior to the start of the PD program. Their claims to using technology in their teaching were further unpacked by considering how frequently they used the available technologies their classroom teaching.

Although various technology resources were available in the CTEs, the teacher educators had used these technologies less frequently in their teaching (see Tables 5.23 and 5.24) prior to

their participation in the PD program. Rather, they were often for non-pedagogical purposes such as preparing examinations and administrative purposes, which are consistent with the findings of other studies (e.g., Voogt et al., 2012). It seemed that the presence of the technology in the CTEs did not increase rates of effective integration of technology in teaching mathematics. This is consistent with other studies that have shown that the potential use of ICT in teaching cannot be realised by the mere presence of an ICT infrastructure (e.g., Etmer, 2005; Hennessy, Harrison & Wamakote, 2010; Hew & Brush, 2007; Peeraer & Van Petegem, 2010; ten Brummelhuis & Kuiper, 2008). The availability of such technologies, however, was a potential asset for further technology integrated teaching practices as recommended by, for example, Etmer (2005), and Hew and Brush (2007) and helpful in designing a PD program (e.g., Mumtaz, 2000; Yusuf, 2005). The design of a PD program pertinent to available technologies and motivating teachers to use those technologies has been recommended by various studies to enhance the teachers' effective use of ICT in teaching (e.g., Kalogiannakis, 2010; Niess, et al., 2009; Schibeci et al., 2008). Accordingly, in this study, the teacher educators' participation in the PD program facilitated the use of available technologies in teaching. For example, the teacher educators reported using computers and software in their mathematics teaching at least once per month; for example, Microsoft Mathematics and GeoGebra, after participating in the PD program (see Tables 5.41 and 5.42 in Chapter 5).

There were flow on effects on the technology use of pre-service teachers, most of whom started to use the available technologies in learning after the teacher educators had participated in the PD program. A greater number of pre-service teachers ($N = 88$), for example, reported using computers and YouTube ($N = 83$) in their learning of mathematics after their teacher educators'

participation in the PD program compared with those that used these technologies before (see Table 5.44). These practices supported effective learning of such mathematics as graphing of logarithmic functions and estimating the value of π (see Sections 5.4.2.1 and 5.4.2.2). It seemed that the teacher educators' use of technology in their teaching motivated the pre-service teachers to use technology in their learning of mathematics. This is consistent with the findings from other studies that have reported teachers' participation in a PD program not only enhanced technology integrated teaching and learnings (Hennessy et al., 2010) but also their students' practices of using available ICTs in learning (Drent & Meelissen, 2008; Getenet, Beswick, & Callingham, 2014). The teacher educators' use of technology in teaching mathematics not only enhanced the quality of their own teaching, but also facilitated preparation of pre-service teachers' teaching with technology. In this regard, researchers have described how teacher preparation programs have recently shifted from an emphasis on teaching about ICT to teaching with ICT (Niess, 2005; Niess, 2011; Ottenbreit-Leftwich et al., 2012). These studies have emphasised that learning to use technology from their teacher educators teaching is a more effective way of preparing pre-service teachers to use technology in their teaching than attempting to teach them to teach with technology.

Although the questionnaire results indicated that the teacher educators used technology in their teaching of mathematics as shown in Tables 5.23 and 5.24, it did not show exactly what, and how this was reflected in classrooms. What exactly happened in the classroom and how it happened was assessed by observations of 24 technology integrated mathematics lessons (12 before and 12 after the PD). The teacher educators' practice prior to and after participating in the PD program was compared. The comparison showed that there were positive changes in their

practices (see Table 5.45) but also some difficulties around the use of some specific software. For example, seven pre-service teachers were unable to use GeoGebra in one observed lesson (see Chapter 5, Section 5.3.3.2).

The teacher educators were not sure how to use appropriate technology, which fitted with pedagogy (STPK) and content (STMK) before participating in the PD program. That is, at this stage, the teacher educators were not observed using technology to support pedagogy for the development of pre-service teachers' understanding (STPK) and selecting an technology that fitted with the special type of mathematics knowledge (STMK) (see Tables 5.13 and 5.14). This indicated that the teacher educators were challenged to relate the pedagogy with the selected mathematical concept and technology, and apply it in their teaching. In spite of this, the teacher educators demonstrated sufficient knowledge about mathematics and various ways of understanding mathematics.

Similar to the results found in the questionnaires (see Table 5.40), the observation results showed that the teacher educators' SPK, SMK and SPMK did not change compared to other constructs of STAMPK (see Table 5.45) following participation in the PD program. There were, however, noticeable changes in the teacher educators' STPK, STMK, and STAMPK during their teaching (see Table 5.45). These results were consistent with their perceptions (see Section 6.1) provided in their questionnaire results. After the PD program, the teacher educators were observed using appropriately selected technology for teaching specific mathematical concepts along with pedagogy selected to facilitate learners' engagements (see detail of observation results at Appendix P). Drent and Meelissen (2008) found that ongoing PD programs helped teachers to acquire the knowledge needed to integrate technology in classroom teaching.

Moreover, Mishra and Koehler (2006) and Niess (2005) showed that teachers should be supported through PD programs to acquire the required knowledge to effectively integrate technology in teaching. As a result, the teacher educators were observed teaching effectively mathematical concepts (e.g., a graph of logarithmic functions effectively using Microsoft Mathematics), which engaged learners in the lessons. The ratings of the teacher educators' STPK, STMK, and STAMPK shifted from the not observed to the observed scale (see Table 5.45). Consistent with this finding, other studies have also shown that ICT based learning in mathematics provide opportunities for learners to engage actively (e.g., Ayub, Mokhtar, Luan, & Tarmizi, 2010; Chee, Horani, & Daniel, 2005; Clayton & Sankar, 2009).

Four lessons delivered by two teacher educators using the mathematical software, namely Microsoft Mathematics and GeoGebra were presented in detail to demonstrate the teacher educators' effective use of technology to teach mathematics (see Sections 5.3.2.1 and 5.3.2.2). Teacher Educator 1 used Microsoft Mathematics to engage pre-service teachers in learning about, and reorganising graphs of logarithmic functions. Although most pre-service teachers recognised the benefits of Microsoft Mathematics, a few believed that the topic should be taught with traditional methods before being explored using technology. Given the inexperience of the teacher educators' teaching with technology, inexpert pedagogy may underpin the pre-service teachers' opinions as well as their difficulty in understanding exactly what was going on. The teacher educators used Microsoft Mathematics to support pre-service teachers to visualise graphs and identify their properties, and to display the graphs as desired based on changing parameters. The use of the software thus facilitated discovery style lessons (see Chapter 5, Section 5.3.2.1).

Similarly, Teacher Educator 2 used GeoGebra to teach the area of a circle inscribing in a regular polygon to estimate the value of π , which facilitated the pre-service teachers' learning to estimate the value of π . A few pre-service teachers were unable to use the software to sketch an inscribed regular polygon with n sides in a unit circle, which hindered their ability to discover and estimate the value of π . This finding was consistent with their perception that they were not sure about the effectiveness of using mathematical software to learn mathematical concepts (see Item 14 in Table 5.18). Drent and Meelissen (2008) showed that ICT should not just be regarded, as a replacement for existing teaching methods; rather, teachers as well as their students must have the required knowledge to use particular technology in teaching and learning.

As noted in the above discussion, in spite of the fact that there were some limitations to the teacher educators' use of technology in teaching mathematics, the observation results showed they appropriately selected a technology, which facilitated the pre-service teachers' engagement in the lessons after their participation in the PD program (see Appendix P). The teacher educators' participation in the PD program appeared to have facilitated their use of mathematics software in their teaching of mathematics. Other studies have also shown that PD programs are necessary to equip teachers with the skills to integrate technology into their teaching and enable them to use available technologies in teaching and learning practices effectively (Fitzallen, 2005; Getenet et al., 2014; Joke Voogt et al., 2012).

6.2. Factors Influencing Teacher Educators' Technology Integrated Teaching

Various factors were identified in the literature as influencing the integration of technology in teaching. As indicated in Chapter 3, Section 3.5, across Africa and most developing countries, there are multiple challenges in bringing technologies into the education process in teaching. The

biggest barriers to use in technology in teaching include teacher motivation, technological literacy and confidence levels, pedagogical expertise related to technology use, appropriate teacher education, support, and teachers' lack of expertise in using technology (e.g., Getenet et al., 2014; Hennessy et al., 2010; Tella et al., 2007). The findings in this study, which influenced the teacher educators to integrate technology in teaching and pre-service learning, were grouped into two main categories; teacher educator and college level factors, consistent with the suggestions by Bingimlas (2009), Drent and Meelissen (2008), and Pelgrum and Voogt (2009). These factors are discussed in turn in the following two sections.

6.2.1. The teacher educator factors. According to Bingimlas (2009), Drent and Meelissen (2008), and Pelgrum and Voogt (2009), teacher educator factors include technical and pedagogical competences, availability and participation in PD program practice, and perceived obstacles. All were considered in this study.

The questionnaire results, particularly in relation to the items of Technology Proficiency Self Assessment (TPSA), showed that the teacher educators had the required skills to use technologies in their daily activities (see Table 5.4). Nevertheless, they indicated that their perceived Technological Knowledge (TK) related to such things as having the knowledge how to solve technical problems and the technical skills needed to use technologies was limited. Although technical skill has been found to be one of the main hindering factors for teacher educators using ICT in their teaching (e.g., Drent & Meelissen, 2008; Hennessy et al., 2010; Hew & Brush, 2007), in this study, technical skill was not a major factor influencing the teacher educators in their technology integrated teaching practices.

The other main barrier was the teacher educators' pedagogical competencies. Liu (2011) asserted that teachers' pedagogical competencies are important for proper integration of technology teaching. In this study, the teacher educators perceived themselves to have the required Specialised Pedagogical Knowledge (SPK) as evidenced in Tables 5.13 and 5.14 in Chapter 5. Studies have shown, however, that success in integrating technology in mathematics teaching is not only dependent upon knowledge of a pedagogy that is used by mathematics teachers, but also on sound ICT and content knowledge to integrate technology into teaching (e.g., Chee et al., 2005). So, although they reported having sound pedagogical knowledge, the teacher educators did not show evidence of effective technology integrated lessons before their participation in the PD program. The teacher educators highly valued the importance of participating in PD programs to support the integration of technology in their teaching but those in which they had participated had been focused on technical skills (see Table 5.15 in Chapter 5, Section 5.1.1). Studies suggest that effective PD programs move beyond acquisition of basic ICT skills (e.g., Borko, 2004; Schibechi et al., 2008; Hea-Jin, 2007) to focus on pedagogical use of ICT. The lack of such PD had hindered the teacher educators in this study from integrating technology in their teaching of mathematics.

In addition to the factors listed in Sections 6.2.1 and 6.2.2, the teacher educators listed challenges influencing the use of technologies in their teaching, which can be considered the teacher educator factors. The most frequently mentioned were lack of experience and awareness in using technology in teaching, and the absence of relevant PD programs (see Table 5.19). These factors were consistent with other findings in the literature concerning factors that

influence teachers' to integrate technology in teaching (e.g. Agyei & Voogt, 2011; Hennessy, Harrison, & Wamakote, 2010; Jomoyiannis, 2010; Niess, 2005).

Similarly, pre-service teachers listed various barriers that hindered their learning mathematics with technology. The most frequently listed barrier was the teacher educators' limited use of technology in teaching mathematics (see Table 5.34). The modelling of technology integrated lessons by teacher educators is one of the factors linked with effective use of ICT in learning by learners (Li, 2003; Lin, 2008; Steketee, 2005; Taylor, 2004; Unwin, 2005). Modelling can support pre-service teachers in seeing the importance of designing and using technology based lessons in their own teaching. In this study, however, the pre-service teachers had limited opportunity to experience their teacher educators' practices of using technology in teaching mathematics.

The teacher educators and pre-service teachers alike valued the contribution that technology can make to learning mathematics effectively with 106 (87%) of participant pre-service teachers and all teacher educators indicating either a high or a very high potential contribution of technology in learning mathematics effectively. Beliefs about the use of technology in teaching have been shown to influence teacher educators' practices with positive beliefs about the usefulness of ICTs is directly related to teachers' classroom practices and the capacity of teachers to integrate ICT into their teaching (Albion, 1999; Higgins & Moseley, 2001; Li, 2003).

6.2.2. The college level factors. Bingimlas (2009), Drent and Meelissen (2008), and Pelgrum and Voogt (2009) listed a number of barriers to integrating ICT in teaching categorised under the college level factors. These college level barriers included lack of access to technology

resources, lack of technical and pedagogical support, lack of effective PD programs and school leadership and support. This study looked at each of these factors as discussed in Chapter 3, Section 3.4.

The teacher educators indicated that they could freely access such technologies as desktop computers, projector systems and the internet but did not use these resources in their teaching of mathematics.

Although there was technical support from ICT coordinators, the findings indicated that this support did not extend to pedagogical support. The technical support included troubleshooting and installing software and the provision of the use of Microsoft Office. These findings of limited support on pedagogical use of technology underlined the need for having pedagogical support from ICT coordinators while the PD program was in progress and has been recommended by, for example, Drew (2011), Liu (2011), and UNESCO (2008).

Lack of relevant PD programs was another barrier for the teacher educators to integrate technology in their teaching of mathematics. In this study, although the teacher educators had attended various PD programs including basic computer skills, SPSS and software used for administrative purposes, they had had little opportunity to participate in PD programs focused on pedagogical use of technology (see Table 5.15). Consistent with MOE (2008) in Ethiopia, the department of mathematics in the two CTEs encouraged teacher educators to use technology in their teaching to increase the quality of mathematics teaching. The departments policy and support for the use of technology in teaching aligned with the previous findings regarding the positive influence the school polices can have on teachers' use of ICT in teaching (e.g., Mumtaz, 2000; Yusuf, 2005).

6.3. Characteristics of a PD Program to Support Technology Integrated Teaching Practices

The PD program was designed using findings from the review of existing literature, as well as the results of the observations, questionnaires and interviews conducted with the teacher educators, the pre-service teachers, and ICT coordinators. The context analysis described Section 5.1 and literature review presented in Chapter 4, were used to formulate the first PD program guidelines (Prototype I). These guidelines were for a PD program focused on pedagogical use of technology and the preparation of exemplar material with an emphasis on available and web based technology. Each of the initial guidelines is discussed below.

As discussed in Section 6.2.2, PD programs, such as workshops and short courses on technical skills were typical of the type of PD programs attended by the teacher educators (see Table 5.15). These had not been successful in helping them to find ways to integrate technology in teaching. The PD program, therefore, considered the influence of technology on pedagogy and content, as a focus of the PD program was vital to enhance the teacher educators' technology integrated mathematics teaching.

Lack of experience and awareness was the most frequently cited factor influencing the teacher educators not to integrate technology in their teaching (see Table 5.19). Accordingly, the exemplar material created and provided as part of the PD program encouraged the teacher educators to create awareness of the possible use of technology in their teaching and the importance of their use of technology as a model for technology integrated mathematics teaching. During the first workshop, the teacher educators confirmed the importance of including an exemplar material in the PD program process to support their technology integrated mathematics teaching after a discussion during the workshop. According to Van den Akker

(1999), there are three advantages of including exemplar material when designing a PD program. Each was emphasised in the findings of this study (see Table 5.31). These advantages were i) creating clear understanding of how to translate the new teaching approach into classroom practice; ii) providing a concrete foothold for the execution of technology integrated lessons that resemble the intended objectives and iii) stimulating teacher educators to practice the intended teaching approach. The results of this study showed that the exemplar material (see Appendix N) was helpful and relevant for the teacher educators in designing similar technology integrated lessons, and performed similar purposes as listed by Van den Akker (1999).

Although there were readily available technologies in the CTEs, their variety was limited. There was ready accessibility to and availability of desktop computers and data projectors as well as internet access. Both the pre-service teachers and teacher educators were aware of these technologies. The teacher educators' ready access to the internet provided an opportunity to include the use of freely available web based mathematics software in the PD program. In Ethiopia, financial constraints meant that freely available software was preferable and this was taken into account in the design of the PD program.

The formation of teams, part of Prototype I, was one of the most effective aspects of the PD program. The teams' formation was used as a strategy to encourage teacher educators to collaborate with colleagues on an ongoing basis, and adapt the PD program to suit their own schedules. This is consistent with findings from other studies (e.g., Looi et al., 2008, Borko, 2004, Levonen, Asela, and Meisalo, 2009) in that formation of small teams is helpful in supporting teachers to talk and reflect upon what is happening in the classroom on a continuous basis. The collaboration within the teams was particularly enhanced by incorporating them in a

PD program with an informal PD portion. Looi et al. (2008) indicated that informal discussion is helpful to dynamically construct knowledge and deepen knowledge while teachers talk about what is actually happening in the classroom. As Bulter, Laknder, Jarvis-selinger and Becingha (2004) suggested, the informal setup provided the teacher educators with the opportunity to share ideas with their colleagues. The teacher educators in this study indicated the importance of an informal PD program in creating a continuous PD program. The teacher educators were in favour of a PD program based on their availability and one which fitted with their own schedule. Three themes emerged during the interview, focus group discussion and final workshop reflection about the advantages of informal PD program arrangement.

- It does not require the presence of all teacher educators at the same time
- Facilitates easy discussions and collaborations with colleagues and
- Creates a feeling for the continuous PD program on participant teacher educators

Various studies have listed multiple characteristics of an effective PD program. These commonly included continuous (Schibeci et al., 2008), collaborative (Rogers et al., 2007), and team based (Butler, Lauscher, Jarvis-Selinger, & Beckingham, 2004). Informal PD programs, however, were not mentioned as a characteristic of effective PD programs in these studies. This study found that an informal structure is an important characteristic of PD to support effective technology integrated teaching practices of teacher educators.

Continued support from the ICT coordinators was also a facilitating factor in the teacher educators' technology integrated teaching through motivating and solving immediate challenges of the teacher educators to use technology in their teaching. Levohen, Aksela, and Meisalo (2009) and Hea-Jin (2007) have shown that continuous support from the experts' facilitated use

of technology in teaching. Roger (2007) further argued that systematic support from an expert initiates and motivates teachers to integrate technology in their teaching.

In summary, the findings of this study in relation to characteristics of the PD program highlight that the teacher educators' participation in a PD program characterised by the pedagogical use of technology, using available technologies, support from ICT expert, team formation, supported by exemplar material, and informal setup, supported teacher educators' effective use technology in their teaching of mathematics.

6.4. Pre-Service Teachers' and Teacher Educators' Perceptions about Technology

Integrated Lessons after the PD Program

The results from the questionnaires and interviews as well as observation sessions showed that both the pre-service teachers and teacher educators were positive about the technology integrated lessons after the PD program. The results of this study showed that the pre-service teachers enjoyed the technology integrated lesson because of three broad reasons:

- The lessons gave the pre-service teachers the opportunity to learn at their own pace
- The lessons opened an opportunity for group discussion and deep engagement
- Learning was simplified in terms of covering a broader concept in a short time

In contrast, the pre-service teachers, in this study, did not enjoy lessons that were dominated by the teacher educators or involved technologies requiring more advanced skills. Similar findings have been reported in various studies (e.g., Chee et al., 2005; Voogt, 2008). Further, Chee et al. (2005) that have shown a technology based learning environment in mathematics enhances students' active engagement and learning opportunities.

The teacher educators listed similar advantages to those mentioned by the pre-service teachers. In addition, they reported that the new approach (teaching technology integrated lessons) gave them the opportunity to try new skills in teaching a particular mathematical concept. A few of them assumed that using technology required more time than the commonly practiced approach (e.g., lecture method). In line with this study's findings, various studies have reported that the use of technology in teaching and learning can lead to significant positive learning and pedagogical outcomes and bring major benefits to both learners and teachers (e.g., Ayub et al., 2010; Su, 2008; ten Brummelhuis & Kuiper, 2008; Voogt, 2008). In particular, technology can enhance teachers' pedagogical effectiveness in terms of students' active engagement and learning opportunities (e.g., Ayub et al., 2010; Su, 2008; ten Brummelhuis & Kuiper, 2008; Voogt, 2008).

6.5. Chapter Summary

This chapter has provided a discussion of the findings of the study in relation to the literature reviewed. The discussion showed the significant role of a PD program that was designed based on context analysis to enhance the teacher educators' STAMPK which later facilitated their effective use of technology in teaching of mathematics. The discussion further indicated that there were challenges with using technology in teaching, however, recommendations were disclosed by the participating teacher educators to overcome these challenges for effective use of technology in teaching. The chapter revealed that both the teacher educators and pre-service teachers had enjoyed technology integrated lessons. The following chapter summarises the major conclusions of the study, answer research question and its implications.

Chapter 7 Conclusions and Implications of the Study

Chapter 6 discussed the findings of the study in relation to the literature reviewed in Chapter 3. The chapter examined aspects of the teacher educators' Specialised Technological and Pedagogical Mathematics Knowledge (STAMPK) that were improved as the result of participating in the PD program. This chapter, Chapter 7, presents the conclusions of the study, implications that can be inferred from the study results and limitations of the study. The chapter begins with recapping the research questions and approach of the study.

7.1. Recapping the Research Questions and Approach

This study documented the design, development and refinement of a Professional Development (PD) program, aimed at enhancing teacher educators' Specialised Technological and Mathematics Pedagogical Knowledge (STAMPK), to facilitate their effective use of technology in teaching mathematics. The study was conducted in two Ethiopian Colleges of Teacher Education (CTEs). It involved 16 mathematics teacher educators, 4 ICT coordinators, and 121 (in Phase 1) and 247 mathematics pre-service teachers (121 in Phase 1 and 126 in Phase 2) and was guided by the following four research questions:

1. What competencies do teacher educators currently have in relation to integrating technology into the teaching of mathematics education?
2. What are the factors that influence teacher educators' integration of technology into teaching?
3. How might an intervention support the development of teacher educators' skill in relation to integrating technology into teaching?

4. What competencies can teacher educators demonstrate in relation to integrating technology into teaching after participating in a PD program?

These research questions were addressed across the three phases of the study, namely:

Phase 1: context analysis, Phase 2: design and improvement of a PD program and Phase 3: assessment and evaluation of the impacts of the PD program. The first or preliminary research phase comprised a contextual and problem analysis and development of a conceptual framework based on a literature review. This phase provided the basis to design the first PD program prototype. The second phase involved setting out design guidelines and optimising the PD program prototypes through 2 cycles of design, formative refinement and revision. The last phase of the study was an assessment (impact evaluation) of the extent to which the PD program had met its objectives. The whole PD program activities lasted for 5 months that involved both workshops and an informal action.

The study used a mixed method approach, which involved the collection of both quantitative and qualitative data informed by an Educational Design Research (EDR) approach. The data were collected using questionnaires, observation checklists, semi-structured interviews and focus group discussions (including workshops).

The following sections present the conclusions of the study in relation to each of the research questions in turn.

7.2. Conclusions

7.2.1. Teacher educators' competencies to use technology in their teaching before the PD program. The first research question related to the teacher educators' knowledge and technology integrated mathematics teaching practices before participating in the PD program. The research question was:

What competencies do the teacher educators currently have in relation to integrating technology into the teaching of mathematics education?

The results related to this research question are organised into three themes. Firstly, the teacher educators' perceived knowledge on Specialised Technological and Pedagogical Mathematics Knowledge (STAMPK) constructs, secondly, the teacher educators' perceived knowledge in using technology in their daily activities, and thirdly, their technology integrated mathematics teaching practices.

The teacher educators in this study did not have high regard for their knowledge of technology (TK), Specialised Technological Pedagogical knowledge (STPK) and Specialised Technological Mathematics Knowledge (STMK) before participating in the PD. However, they showed a high regard for their Specialised Mathematics Knowledge (SMK), Specialised Pedagogical Knowledge (SPK), and SPMK (see Tables 5.6, 5.7 and 5.8). Although teacher educators had a low perceived knowledge of technology, they reported having a better opportunity to work with technology. These were favourable conditions for the teacher educators' effectiveness to integrate technology in their teaching of mathematics.

The teacher educators' Technology Proficiency Self Assessment (TPSA) was another variable considered as part of teacher educators' competencies to integrate technology in their

teaching. They agreed on having proficiency in most of TPSA items in their daily activities. They were, however, unsure about using particular software applications including GeoGebra for teaching mathematics. Having a high proficiency on most of the TPSA items was an indication that the teacher educators had the preliminary technology knowledge to use technology in their teaching. This was considered a favourable condition in designing the PD program in the later phase of the study.

Twelve lessons were observed and audited using the observation checklist before the teacher educators' participation in the PD. The results showed that their use of technology in teaching was limited, particularly, in their use of technology to support pedagogy for the development of students understanding (STPK). However, the teacher educators were confident in appropriately spelling out the subject matter (SMK) in the designed lesson in contrast to their limited skill in clearly designing technology that could support transfer of knowledge.

7.2.2. Factors influencing teacher educators' integration of technology in teaching.

The second research question addressed the factors influencing teacher educators to integrate technology in their teaching of mathematics. The research question was:

What are the factors that influence teacher educators' integration of technology into teaching?

In spite of the fact that using technology in teaching is believed to be a means of increasing the quality and equity of education in particular mathematics teaching, including many developing countries in Africa, mathematics teachers seldom use technologies in their teaching due a range of factors (e.g., Hennessy et al., 2010).

The teacher educators' ability to use technology to support pedagogy and the teaching of specific content is a major barrier resulting in limited technology use in teaching. As a result, many studies have considered teachers' technological pedagogical content knowledge. In this study, the focus was specifically on mathematics teaching and so the requisite knowledge was conceptualised as Specialised Technological and Pedagogical Mathematics Knowledge (STAMPK). In this study, the most frequently mentioned challenges to effective technology integrated mathematics teaching were the teacher educators' lack of experience and awareness in using technology in teaching and absence of PD programs focused on the pedagogical use of technology. The lack of a PD program, which fitted with the context and focusing on pedagogical use of technology in teaching was another major barrier. The study indicated that technical support from ICT coordinators was available in two CTEs, however, the support did not extend to pedagogical use of technology. The limited support on pedagogical use of technology was an underling factor influencing the teacher educators' use of technology in their teaching of mathematics. The presence of the technology in the CTEs did not appear to facilitate the effective integration of technology in the teacher educators' teaching of mathematics. It was, however, a potential asset for further technology integrated teaching practices scaffolded by appropriate PD.

7.2.3. Interventions that supported teacher educators to use technology in their mathematics teaching. The third research question for the study looked at the characteristics of an intervention program designed to support the development of teacher educators' skill in relation to integrating technology in mathematics teaching in two Ethiopian Colleges of Teacher Education context. The research question was:

How might an intervention support the development of teacher educators' skill in relation to integrating technology into teaching?

The context analysis and active involvement of participants of the study supported the design of the PD program, which appeared to shift to the teacher educators' perceived knowledge to use technology in teaching (STAMPK) and their classroom practices in using technology to teach mathematics. The PD program had particular characteristics, which fitted with the context of the study. These involved a focus on the pedagogical use of technology, provision of exemplar material, and an emphasis on using available and the web based technologies, the formation of teams, support from ICT coordinators, and an emphasis on informality in the PD arrangements. Each characteristic contributed positively increasing the effective use of technology by the mathematics teacher educators.

The emphasis of the PD program on the pedagogical use of technology facilitated the teacher educators' creation of relationships between the pedagogy, the selected mathematical concept, and the technology enabling them to apply them in their teaching. In this regard, the teacher educators' use of the STAMPK framework appeared to facilitate the systematic design of their own lesson. Particularly, using the framework as a pre-cursor to the PD program was

imperative in developing an understanding among the teacher educators of technology integration with the pedagogy and content.

The preparation of the exemplar material enabled the teacher educators to use it as a point of reference to design their own technology integrated lessons. The fact that the PD program was based on the available technologies was a result of consideration of the context of the study and was useful to its effectiveness.

The teacher educators used the formation of teams as an opportunity to collaborate with their colleagues on an ongoing basis. The PD program supported the teacher educators to reflect upon and share their experiences with their small teams for feedback and future improvement. The formation of teams also supported the teacher educators to engage with the PD program as it fitted their own schedules. Particularly, the informal PD setup supported the teacher educators to participate in the PD program in teams without all being physically present at the same time. In addition, it provided an opportunity for teacher educators to easily collaborate and add reflection on issues at any time, and it created a sense of continuity of the PD. The continuous pedagogical support from ICT coordinators helped to motivate the teacher educators to integrate technology in their teaching of mathematics by encouraging and solving challenges of the teacher educators in relation to the pedagogical use of technology.

7.2.4. Teacher educators' competencies to use technology in their mathematics teaching after the PD program. The impact on teacher educators' technology integrated teaching practices resulting from participating in the PD program was the focus of the final research question which was:

What competencies can teacher educators demonstrate in relation to integrating technology into teaching after participating in a PD program?

The teacher educators' participation in the PD program characterised by the features described in Section 7.2.2, resulted in improvement in their perceived knowledge of how to use and integrate technology teaching practices in their mathematics teaching. It appeared that the teacher educators' higher regard for their integrated knowledge of each technological construct included in STAMPK after their participation in the PD program was associated with positive change in their effective technology integrated mathematics teaching as evidenced by the classroom observations.

Their improved use of technology in teaching also facilitated the preparation of the pre-service teachers' teaching with technology. The technology integrated lessons enhanced the pre-service teachers' active engagement with the relevant mathematics. The effective use of technology by the mathematics teacher educators were a more effective way of preparing pre-service teachers to use technology in their teaching than learning to teach with ICT (Niess, 2005; Niess, 2011; Ottenbreit-Leftwich et al., 2012).

7.3. Implications of the Study

The findings from this study are significant for Colleges of Teacher Education (CTEs) in Ethiopia and in similar contexts in developing countries. They are especially relevant to those looking to improve mathematics teaching with technology with the teacher educators' recognising that this can influence pre-service teachers use of technology. The findings have implications for policy and practices, mathematics teaching in developing countries and can inform similar studies in mathematics education. The following sections discuss the implications

for policy and practice, mathematics teaching in developing countries and its contribution in the field of mathematics education.

7.3.1. Implications for policy and practices. The findings of this study indicated that the design process of the PD program was effective in developing PD that positively influenced the teacher educators' practices to use technology in teaching mathematics. These results have two broad implications involving PD programs, and curriculum design processes for the preparation of pre-service teachers. These are discussed in detail on the following subsections.

7.3.1.1. PD program design: The context of the study was taken into account when designing the PD program. It played an important role in providing rich data for designing the real examples, practical content, and relevant scenarios to be used in PD program. The study identified that context analysis was vital when suggesting PD guidelines, particularly in developing countries where there is limited research about PD practices but where PD program scenarios of developed countries are often adopted. It may prove fruitless to adopt PD principles, which are an appropriate fit in one context but not in others. The process used in this study to analyse the context and incorporate the results of that analysis on the ensuing PD program provides a model that can be applied in other contexts

One particular feature of the PD program designed in this study was the informal setup of the PD program practices. This setup facilitated the teacher educators' participation based on their available time, providing continuous involvement without being physically together. Hence, suggesting and designing a context based PD program is a promising strategy for effective and relevant PD program design, which could be considered by policy developers in other contexts.

7.3.2. Curriculum design and pre-service teachers' preparation: As shown in Chapter 3, Section 3.6.1, despite the wealth of commentaries on teacher education programs, there is little empirical research focused on teacher educators. The findings of the study have shown that the teacher educators' improved practices to use technology in teaching mathematics not only enhanced the quality of their teaching, but also facilitated preparation of pre-service teachers' teaching of mathematics with technology. Learning to use technology from their teacher educators' teaching was shown to be a more effective way of preparing pre-service teachers to use technology in their teaching than learning to teach with technology. In addition, rather than teaching technology use as separately for pre-service teachers, designing curriculum materials for use by teacher educators on subjects such as mathematics which incorporate technology for teaching mathematics concepts could be a more effective way of supporting pre-service teachers to use technology in their future teaching.

7.3.3. Implications for mathematics teaching in developing countries. The study documented cases of classroom practices such as teaching with Microsoft Mathematics and GeoGebra. For example, the pre-service teachers readily used Microsoft Mathematics to visualise graphs of logarithmic functions and identify their properties. The cases demonstrated the potential of freely available software to help teachers in developing countries and other contexts in which resources are limited. Such software relatively straightforward to download for multiple platforms or the software can be launched directly from the Internet. The study provided an example of how GeoGebra can be used to explore a basic geometric concept. These software capabilities were particularly important for the chosen mathematics content because difficulties had been identified in relation to the pre-service teachers' ability to distinguish these concepts. In

both cases, the focus was on the use of specific software to teach a specific mathematical concept, with the study finding that software with similar capabilities could be useful for other mathematical concepts.

7.3.4. Contribution to the field. Implications for mathematics education field can be drawn from the three parts of the study, namely from its methodological approach, subject specific knowledge framework (STAMPK), and its findings.

7.3.4.1. Methodological approach: Studies have criticised trends of educational research for its emphasis on practices rather than its required focus in practice (e.g., Anderson & Shattuck, 2012). This study drew upon EDR to improve practices. The study incorporated both research on practice and research in practice. That is, the first phase of the study, which focused on practice (for example, the context analysis to design the PD program), was used as a springboard to improve educational problems in practice (for example, improving the mathematics teacher educators competencies to use technology in their teaching by designing the PD program). That is, the PD program, with the detailed analysis of the context as its base, improved the mathematics teacher educators' practices in using technology in teaching mathematics. This more practical approach provides a model that could be adopted for studies aimed at improving practices.

7.3.4.2. Subject specific framework. The teacher educators' use of the STAMPK framework appeared to facilitate the systematic design of their own lesson. The framework was vital in developing an understanding among the teacher educators of technology integration with the pedagogy and specific mathematics content with the aim of achieving better learning outcomes. Using the mathematics specific STAMPK framework yielded a different, but similarly

useful insight into the knowledge demands of technology integrated mathematics teaching. Much work is needed to explore such options, but the framework provides a starting point for one such line of inquiry.

The STAMPK framework further supported the framing and construction of data gathering instruments, including questionnaires, to measure mathematics the teacher educators' knowledge for technology integrated mathematics teaching. The required instrument design process followed steps based on the STAMPK framework. The steps in the development of the questionnaire were consideration of the context in which the questionnaire would be used, comparison of proposed items with an existing instrument, expert review, and pilot testing. The process described provides a model for other researchers interested in adapting generic tools for subject specific use.

7.3.4.3. Findings: The study followed a procedure in which each phase contributed to the development of the subsequent phase. Specifically, the context analysis supported the design of context fitted intervention in the form of PD program to improve the teacher educators' technology integrated teaching practices. Finally, the PD program improved the teacher educators' practices. Such a design process could be applied in similar contexts in Ethiopian Colleges of Teacher Education and beyond to address a range of educational problems.

7.4. Limitations of the Study

The intervention, in the form of a PD program, took a total of 5 months. EDR, however, usually takes a longer period so that a PD program can be developed and refined through multiple iteration of the design processes (Design-Based Research Collective, 2003; Wang & Hannafin, 2005). Time constraints meant the investigator was unable to do multiple prototypes

for the PD design with the study comprising “a work on progress” on the basis of which recommendations for a similar PD program can usefully be made. In the current study, there was a run of just two cycles of PD prototypes to be implemented. A greater number of cycles would have resulted in a more refined PD program and perhaps led to stronger findings.

As discussed in Chapter 4, Section 4.2.1, the researcher had played a role of facilitator during the PD program process. It could be interesting to assess the teacher educators’ practices of using technology after the researcher was no longer in the facilitator role.

7.5. Chapter Summary

Chapter 7 revisited the research questions followed by the conclusions of the study in line with the research questions. The study has also implications, which can be applied in similar contexts and beyond. While answering the research questions, the study also brought a number areas for research which can be explored further in future studies.

Overall, the study showed a design based approach to designing a PD program aimed at improving mathematics teacher educators’ practices to use technology in the teaching of mathematics for learners’ can have positive outcomes.

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Appendix A

Ethics application form and approval letter from Human Research Ethics Committee

(Tasmania) Network

SOCIAL SCIENCES HREC FULL COMMITTEE APPLICATION

Important

Please email an electronic version of this application plus the supporting documentation as **Microsoft Word documents** to:

Katherine.Shaw@utas.edu.au

A .pdf attachment is acceptable for appropriate documents, eg., advertisements, posters, etc.

A signed hard copy must also be sent to: Katherine Shaw, Private Bag 1, Hobart, 7001
We will use the electronic version to meet agenda deadlines and the signed copy can follow in due course, once signatures have been obtained.

If you have any questions, please call: 6226 2763

1. Title of proposed investigation

Please be concise but specific. Titles should be consistent with those used on any external funding application.

Enhancing mathematics teacher educators' technological, pedagogical, and content knowledge through collaborative professional development: Ethiopia

2. Expected commencement date:

Expected completion date of project

2012	2014
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3. Investigators:

CHIEF INVESTIGATOR

Note: This is the researcher with ultimate responsibility for the research project.

The Chief Investigator cannot be a student.

Given Name	Surname		
Kim	Beswick		
Staff Position:	Associate Professor in mathematics education	Qualifications:	PhD
Staff ID:	02186714		
School & Division:	Education		
Contact Address:	Locked Bag 1307, Launceston ,Tasmania 7250, Australia		
Telephone:	+61 3 6226 7679	Email:	Kim.Beswick@utas.edu.au
			(Required)

A. CO-INVESTIGATOR(S)

i) Given Name	Surname		
Rosemary	Callingham		
Staff Position:	Associate Professor in mathematics education	Qualifications:	PhD
Staff ID:			
Contact Address:	Locked Bag 1307, Launceston ,Tasmania 7250, Australia		
Telephone:	+61 3 6324 3051	Email:	Rosemary.Cllingham@utas.edu.au
			(Required)

ii) Given Name	Surname		
Staff Position:		Qualifications:	
Staff ID:			
Contact Address:			
Telephone:		Email:	

(Required)

C. STUDENT Investigator(s):

i) Given Name

Seyum

Surname

Getenet

Gender: Male **Date of Birth:** 06/06/1980 **Preferred Title:** Mr

Student Number: 156770 **Level:** PhD

Contact Address: Locked Bag 1307, Launceston ,Tasmania 7250, Australia

Telephone: +61402271682 **Email:** Seyum.Getenet@utas.edu.au

(Required)

ii) Given Name

Surname

Gender: _____ **Date of Birth:** _____ **Preferred Title:**
Mr / Ms / Miss /Mrs /Dr

Student Number: _____ **Level:**
Undergraduate / Hons / Masters /
Postgraduate Diploma / PhD

Contact Address: _____

Telephone: _____ **Email** _____
(Required)

4. Is this a student project that requires School approval
(eg., program of study approval)?

Yes ☒ No ☐

If yes, the project has been:

- a) Submitted ☐ i) Approved ☒ ii) Not yet approved ☐
b) Not yet submitted ☐

5. Approvals from other Departments / Institutions

Does this project need the approval of any institution other than the University of Tasmania and/or the Department of Health and Human Services (e.g., Department of Education, particular wards in hospitals, prisons, government institutions, or businesses)?

Yes ☒ No ☐

If yes, please indicate below the Institutions involved and the status of the Approval.

Name of Other Institution(s): Amhra Regional Education Office and -----and Initial Teacher Education Colleges Status: Informal discussion has be conducted and they were interested with the research

The research does not require approval of HREC in Ethiopia. The country research committee is limited to National Health Research Ethics Review Committee. Hence, this research can be carried out without the process National Health Ethics Review Committee.

Does this project need the approval of any other HREC? Yes ☐ No ☒

If YES, please indicate below which Human Research Ethics Committee, and the status of the application.

If NO, why not?

The research does not require approval of Social Science Human Research Ethics Committee in the context of the country in which the study will be undertaken. The country research committee is limited to National Health Research Ethics Review Committee. Hence, this research can be carried out without the process National Health Ethics Review Committee.

Other HREC(s):

Status:

6. Is the investigation a follow-up of a previous study? Yes ☐ No ☒

If yes, what is the ethics reference number of that study?

What was the title of that study?

7. Funding

Under the National Statement (2.2.6) a researcher must disclose:

- the amount and sources or potential sources of funding for the research; and
- financial or other relevant declarations of interest of researchers, sponsors or institutions

Is this research being funded? Yes ☐ No ☒

*If yes, please detail amount and source of funds
(NS 5.2.7)*

If this application relates to Grant(s) and/or Consultancies, please indicate the Title and Grant Number relating to it

If no external funding has been obtained, please indicate how any costs of research will be met:
The study will be conducted by the fund allocated by the Faculty of Education for PhD research purposes.

Do the investigators have any financial interest in this project? Yes ☐ No ☒

If yes, please give details:

8. Keywords Please provide definitions for any technical terms and acronyms

Term	Lay Explanation
Pre-service Teachers:	Prospective teachers of primary school (age 7 -14) mathematics
Teacher Educators:	Teachers of pre-service mathematics teachers
Mathematics Education:	The practice of teaching and learning mathematics
Information Communication Technology (ICT) :	Refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc.
Collaborative Professional Development (CPD):	Nurturing of learning communities within which teacher educators try new ideas, reflect on outcomes, and co-construct knowledge about teaching and learning.
Technological Pedagogical Content Knowledge (TPACK):	Facilitating pre-service teachers learning of a specific content through appropriate pedagogy and ICT in a particular context.

9. Rationale and Background for the Project:

Has the research proposal, including design and methodology, undergone a peer review process?

Yes ☒

No ☐

If YES - provide details:

The proposal has been reviewed by the faculty research committee

If NO – please explain why:

Please give a plain English description of the aims of this study.

This study is proposed with the aim of exploring the impact of collaborative professional development on pre-service mathematics teacher educators' technological, pedagogical, and content knowledge in Ethiopian Colleges of Teacher Education (CTE). Therefore, the study will

- Investigate teacher educators current skill and motivation of using ICT into teaching
- Explore factors influencing teacher educators to integrate ICT into teaching
- Investigate pre-service teachers current motivation and interest for ICT integrated lessons
- Investigate professional needs of teacher educators to integrate ICT into teaching
- Investigate pre-service teachers' motivation and interest for ICT integrated lessons after intervention activities.
- Investigate teacher educators' skill and motivation to integrate ICT into teaching after/during intervention activities.
- Investigate the characteristics of an intervention activity that will help teacher educators to integrate ICT into teaching.

The public education system in Ethiopia has a stated objective to use the development, deployment and exploitation of ICTs to help develop Ethiopia into a socially progressive and prosperous nation with a globally competitive, modern, dynamic and robust economy. Simultaneously, the education sector has been identified by the Government as a priority area. Thus, Ethiopia presents a good example of a developing country in which the use of ICTs in education has received central support (Hare, 2007). However, the formal curriculum of the Ethiopian school system is characterized as low in quality. As a result, the government of Ethiopia is emphasising the provision of quality education at all levels and subjects. Particularly, because of its importance, the government is committed to ensuring the provision of high quality mathematics education. Of major concern are the consistently low achievement levels in mathematics among students at all levels. One cited problem for this is the quality of teachers (Hoot, 2005; Ministry of Education (MOE), 2003). Thus, the demand for quality education is high in the Ethiopian education sector especially in CTE in preparing mathematics teachers of primary schools. As a result, the MOE is launching The National ICTs in Higher Education Initiative. It is believed that the educators should have the skill to integrate ICT into teaching to help and train pre- service teachers to integrate ICT in teaching. However, little attention is given to professionalising teacher educators, which might support the development of what teacher educators need to know and do in order to meet the complex demands of preparing teachers for the 21st century through the use of ICT. Hence, there is a need to professionalize teachers' educators in this regard (Darling-Hammond, 2006). Despite the stated needs and benefits of aligning educational reform with collaborative and continuous professional development to integrate technology in the teaching, reform in Ethiopian CTE has ignored professional development of almost all kinds. Little is known in Ethiopia about the potential of collaboration in relation to teacher educators' professional development on technological, pedagogical and content knowledge. Therefore, this study endeavours to explore the potential of this approach for mathematics teacher educators. More specifically, the study will explore how collaborative professional development enhances pre-service mathematics teacher educators' technological, pedagogical and content knowledge in Ethiopian CTE to help teacher educators to integrate ICT in their teaching.

Please give a plain English description of the *justification* for this study.

A great amount of research has shown that the use of ICT as a learning tool within meaningful contexts of learning can lead to significant educational and pedagogical outcomes in the schools and bring major benefits to both learners and teachers (Ayub, Mokhtar, Luan, & Tarmizi, 2010; Johnston & Barker, 2002; Su, 2008; Voogt, 2008; Waxman, Connell, & Gray, 2002; Webb, 2005). Particularly mathematics education constitutes a privileged subject matter when considering ICT integration to enhance teachers' instructional potential and students' active engagement and learning opportunities. As a result, integrating ICT into mathematics education is currently receiving global attention from literally all nations in the world. However, teachers in higher education seldom are seen integrating the available technologies in the teaching learning process. Different factors are most likely responsible for this. Nowadays, effective technology integration, particularly teachers' lack of knowledge of technology and pedagogy which is essentially the idea of pedagogical content knowledge of Shulman (1986) as it extends into the domain of teaching with technology (it can be termed "technological pedagogical content knowledge") is taken as one serious factor. In this regard, teaching with technology requires the development of technological pedagogical content knowledge which is the knowledge of how to facilitate students' learning of a specific content through appropriate pedagogy and technology (Mishra & Koehler, 2006). This requires teachers to reflect on the critical relationships between content, technology and pedagogy (Koehler & Mishra, 2009; Niess, et al., 2009). However, the ability of teachers to establish the relationship between content, pedagogy and technology, depends largely on the way teachers were taught to integrate technology into teaching and the way these components are treated in professional development of teachers in using technology in teaching and learning (Jimoyiannis, 2010; Koehler, & Mishra, 2009).

Hence, this study is meant for introducing a professional development to enhance teacher educators' skill and motivation to integrate ICT into their teaching. During the study, pre-service teacher educators at _____ and _____ CTE will get an opportunity to experience how to integrate technology, pedagogy and content into teaching. This will give an opportunity for mathematics teachers' educators to learn the best way of using technology to enhance learning. When they learn this, educators may be interested to extend the knowledge to more innovative and creative learning support through technology. Moreover, the study will make the following contributions in terms of knowledge of mathematics education:

- Serve as reference material for the development of policy issues and provide professional development materials in the field of integrating technology in the teaching learning process in general and in the area of mathematics education in particular.
- Introduce a culture of well-planned in-service professional development to the Ethiopian teacher education system. It will help Ethiopian CTE administration and other concerned bodies develop favourable attitudes towards the professional development activities of teacher educators.
- Help Ethiopian pre-service mathematics teacher educators to improve their technological, pedagogical and content knowledge, thereby improve their teaching performance, and thus enhance pre-service teachers learning.
- Add to the knowledge base of linking mathematics education, professional development and technology integration in teacher education institutes.
- Encourage this researcher and other professionals in the field to carry out further studies on this same issue and other related topics.

Please list the most relevant and recent literature references, both by the investigator and/or by

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10. Participants

Number of Participants

How many participants do you intend to recruit?

Table 1: Participants of the study

Participants Involved	Number	Note
Teacher Educators	20	All teacher educators
Pre-service teachers	120	All 1 st and 2 nd years
ICT Coordinators	2	
Total	142	

The study will include all teacher educators, ICT coordinators and 1st and 2nd year pre-service teachers at two CTE. The justification is provided below.

Provide justification for the number of participants you intend to recruit.

The study will be conducted at two initial teacher education colleges. As a result, different informants will be sources of data. Pre-service mathematics teacher educators, pre-service teachers and ICT coordinators will be sources of information. Hence, in the study, 20 mathematics teacher educators, 2 ICT coordinators and 120 pre-service teachers (1st and 2nd year and 60 pre-service teachers from each college) will be participants of the study. Therefore, a total of 142 participants will take part in the study. In the study, all mathematics teacher educators will be involved. However, only 1st and 2nd year pre-service mathematics teachers will be participants of the study. Third year pre-service teachers are often out of campus for practice teaching; therefore, it is inappropriate to involve these groups in the study.

It is expected that there will be 10 mathematics teacher educators in each college; hence, all are taken as the study participants. The number of pre-service teacher per year level is assumed to be 30; hence, all pre-service teachers of mentioned year level will involve in the study. As observation sessions will take place in the authentic classroom settings, all pre-service teachers are assumed to be potential participants of the study.

Selection of Participants

Clearly describe the experimental and, where relevant, control groups. Include details of sex, age range, and any special characteristics (ethnic origin, demographic details, health status etc).

Give a justification for your choice of participant group(s).

10. Participants

Mathematics teacher educators, mathematics pre-service teachers and ICT coordinators are supposed to be sources of information of the proposed study. Teacher educators and pre-service teachers are taken as the study participants as they are main actors of the study. The ICT coordinators are helpful in facilitating the research process and reflecting on teacher educators' skill and motivation to use ICT into teaching. Moreover, the ICT coordinators will help the effort made in investigating the context of the college in using ICT in teaching by teacher educators and related factors.

All teacher educators and pre-service teachers who showed an interest to fill the questionnaire will be invited to participate in the questionnaire. In addition, all pre-service teachers who showed interest to participate in the observation session will be included.

However, as few participants are required to participate in focus group discussions (6 teacher educators, and 6 pre-service teachers), interview (10 teacher educators and 10 pre-service teachers) and observation sessions of 6 teacher educators, participants will be purposefully selected with the help of ICT coordinators and teacher educators. The purposeful selection will be based on participants' ability to express issues well and reflective. This holds true if the number of participants who showed an interest in focus group discussion, interview and observation session is greater than the required number.

Note that as the medium of instruction is in English in both colleges, all the instruments are prepared in English.

Will the project involve any of the following participants? Please note that any random sample of the population may possibly include all of these participants, unless the study has been designed to specifically exclude a particular type of participant.

		Yes	No	Possibly
(a) Pregnant Women?	(NS 4.1)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(b) Minors, i.e. children under 18 years of age?	(NS 4.2)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(c) People highly dependent on medical care who may be unable to give consent?	(NS 4.4)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(d) People with a cognitive impairment, an intellectual disability, or mental illness?	(NS 4.5)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(e) People who may be involved in illegal activities?	(NS 4.6)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(f) People in other countries?	(NS 4.8)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(g) Aboriginal and Torres Strait Islander peoples?	(NS 4.7)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(h) People who are identifiable by their membership of a cultural, ethnic or minority group?		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

10. Participants

For each “Yes” or “Possibly”, show how your research complies with the relevant section in the *National Statement*.

The research will be conducted in the country where there is no need to go through ethical approval process. The research will be conducted with the co-researcher student who is familiar with the context. The student researcher has lived and worked in the area in which the research will be conducted. He has been a teacher educator in that context for more than 3 years. In addition, the student researcher is an Ethiopian and completed his teacher education program in similar teacher education colleges. This complies with the National Ethics Statement of Section 4.8.5 and 4.8.7.

In addition, there will be an incidental possibility of including “Pregnant Women” in the study as 142 participants will participate in the study; however, participating in the research will not present danger to the participant. If pregnant women experience any pain or physical distress during the activities of the research project, the activity will be ended immediately. This complies with the national Ethics Statement, Section 4.1.8.

If you answered “Yes” to (g) you must also attach a statement indicating how Aboriginal and Torres Strait Islander sensitivities will be recognised (see the following publication for guidance: <http://www.nhmrc.gov.au/publications/synopses/e52syn.htm>)

Recruitment of Participants

How will participants be recruited? From where will your participants be recruited?

Give specific details about how participants will be recruited. Some questions to consider include:

- Are you recruiting through advertisements? If so, indicate where they will be placed and append a copy
- Are you recruiting through 3rd parties like associations, schools or clubs? If so, detail how you will approach the organisations and the process that the stakeholders will use to pass on information to potential participants. Please attach copies of letters of introduction, emails, and telephone preambles if appropriate
- Are the participants University or DHHS staff, or regular patients in a particular clinic? If so, detail how they will be approached i.e. through personal invitation, email etc

The participants will be selected based on following the procedure that is best practiced in the country. The initial teacher education colleges are administered and financed by the regional government, therefore, the researchers has to get permission from the regional government (it is a matter of making signal). The regional educational office will be endorsing the research to be done in the colleges. Finally, the college will approve the study to be conducted in the respective departments. Together with the Academic and Research vice Deans (ARVDs) and teacher educators, the participants of the study will be recruited. Therefore, the procedure of recruiting participants is as follows:

Table 2: **Participant Recruitment procedure**

Activity	Decision maker	Necessary requirements	Note
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Get permission to conduct the research in the colleges	The regional education office	Support letter from the institution (UTAS)	Pre-approval is done through contact
Get permission to conduct the research in the respective department	The college deans	Support letter from regional education office	Pre-approval is done through contact

After all these stages, the researcher will have frequent contact with teacher educators and department heads. As a result, pre-service teacher participants will be selected in collaboration with teacher educators. In the process, the researcher will assure that there will not be coercion from teacher educators on pre-service teachers to participate in the study. The pre-service teachers' participation in the study will be totally voluntarily. As a consequence, the distribution of information sheet and consent form, and collection of signed consent form will be according to the following procedures.

The researcher will contact the initial teacher education colleges after successful approval from the regional education office. The ARVDs will be asked to distribute the information sheet and consent form for teacher educators which invites their willingness to participate in a survey questionnaire. The survey will allow participants to indicate their willingness to participate in one or more of the activities which includes an interview, professional learning workshop, and focus group discussion and observation sessions. Participants who are interested to participate in one or more of them will be invited to provide their phone number or email. As a result, interview, professional learning workshop, focus group discussion and observation session participants will be selected from those who showed their willingness in survey questionnaire.

In the same vein, participant teacher educators who show up to participate in the study will be asked to distribute the information sheet and consent form for pre-service teachers which invites their willingness to participate in a survey questionnaire. The survey will allow pre-service teachers to indicate their willingness to participate in one or more of the activities which includes an interview, focus group discussion, observation sessions and final questionnaire. Participants who are interested to participate in one or more of them will be invited to provide their phone number or email. In addition, ARVDs will be asked to distribute the information sheet and consent form for the ICT coordinators to participate in an interview. If the ICT coordinators are interested to participate in an interview, they will be invited for another interview and professional learning workshops participation.

11. Data Source and Identifiability

Does the project involve information sourced from databanks?

(NS 3.2) Yes ☐ No ☒

If yes, state which one(s) and indicate what permission for access is required. Include a description of any conditions of access and attach any relevant approvals.

Is the data collected about individual participants:

a) Non- identifiable?

Non-identifiable data is data which have never been labelled with individual identifiers or from which identifiers have been permanently removed, and by means of which no specific individual can be identified. A subset of non-identifiable data are those that can be linked with other data so it can be known that they are about the same data subject, but the person's identity remains unknown.

☐

b) Re- identifiable?

Re-identifiable data is data from which identifiers have been removed and replaced by a code, but it remains possible to re-identify a specific individual by, for example, using the code or linking different data sets.



c) Individually Identifiable?

Individually identifiable data is data where the identity of an individual can reasonably be ascertained. Examples of identifiers include the individuals name, image, date of birth or address, or in some cases their position in an organisation.

Table 3: Data type

Type of Data	Source	Data type	Note
Survey Data (Questionnaire)	- Teacher educators - Pre-service teachers	Non- identifiable	Those participants who elect to complete only the survey.
Audio Recorded interview	- Teacher educators - Pre-service teachers - ICT coordinators	Re- identifiable	Pseudonyms will be used to link with a transcribed data to protect their identity
Audio Recorded group discussion	- Teacher educators - Pre-service teachers	Re – identifiable	Pseudonyms will be used to link with a transcribed data to protect their identity
Video Recorded	- Teacher educators -Pre-service teachers	Individually identifiable	Pseudonyms will be used to link with analysed video. In addition, the video will be viewed by the researchers only for analysis purpose.



In addition, although the investigator will maintain confidentiality, it is not possible to guarantee that other group members will do so in the focus group discussion.

Note that as indicated above, video recording will be carried out at two points of the study specifically, i) during teacher educators' practical use of ICT in teaching and ii) during the proposed final evaluative workshop. However, both video tapes will be viewed by the researchers only for analysis purposes. Moreover, the transcribed audio data and analysed video will be anonymous as the data will be coded.

12. Federal Privacy Legislation

The following questions are part of the requirements concerning federal privacy legislation.

(a)	Is this project medical research (including epidemiological research?)	Yes	<input type="checkbox"/>	No	<input checked="" type="checkbox"/>
		Go to (b)			
	If yes, will you require the use or disclosure of information from a Commonwealth agency?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
	If yes, will the information to be disclosed be personal information, i.e. identifiable information?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
	If yes, will you be obtaining consent from the individuals to whom the information relates?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>

(b)	Is this Research relevant to public health or safety, or to the management, funding or monitoring of a health service?	Yes	<input type="checkbox"/>	No	<input checked="" type="checkbox"/>
Go to (Question 13)					
	<i>If yes, does the research involve the collection, use or disclosure of information from a private sector organisation?</i>	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
	<i>If yes, will you be collecting, using or disclosing health information</i>	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
	<i>If yes, will consent be obtained from the individuals to whom the health information relates?</i>	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>

13. Procedures

Describe the procedures to which participants will be subjected or the tasks they will be asked to carry out (**please detail exactly what you will be doing**).

Researchers should explain how the investigators intend to conduct the study including the methodological approach, the specific procedures employed and the methods of analysis of data. This should be consistent with the aims of the project.

Please provide detailed procedures (describe exactly what you are going to do):

The study will employ a combination of qualitative and quantitative research methods to analyse the data of the study. Moreover, the study will employ a design research and technological pedagogical and content knowledge framework. The research will pass through three stages described by Plomp (2009):

1. Stage 1: Preliminary research,
2. Stage 2: Prototyping, and
3. Stage 3: Assessment phases.

These stages will be carried out to investigate the following themes:

Theme 1: Investigate teacher educators current skill and motivation of using ICT into teaching

Theme 2: Explore factors influencing teacher educators to integrate ICT into teaching

Theme 3: Investigate pre-service teachers current motivation and interest for ICT integrated lessons

Theme 4: Investigate professional needs of teacher educators to integrate ICT into teaching

Theme 5: Investigate pre-service teachers' motivation and interest for ICT integrated lessons after intervention activities.

Theme 6: Investigate teacher educators' skill and motivation to integrate ICT into teaching after/during intervention activities.

Theme 7. Investigate the characteristics of an intervention activity that will help teacher educators to integrate ICT into teaching.

Table 4: Overview of the study

Participants	Activity	No of participants from the two colleges	Data collection instrument	Stage	Purpose for theme (s)
Pre-service teachers	Interview	10	Audio recording	1	1, 3 and 4
				3	5 and 6
	Focus group discussion	6	Audio recording	3	6, 7
	Filling questionnaire	120	Questionnaire	1	1,3 and 4
				3	5 and 6
	Observation	120 (All students who will be in the classroom)	Video recording	1	1, 2 and 4
				3	6, 7
Teacher educators	Filling questionnaire	20	Questionnaire	1	1, 2 and 4
				3	5
	Interview	10	Audio recording	1	1, 2 and 4
				3	6, 7
	Focus group discussion	6	Audio recording	1	1
				3	6
	Observation	6	Video recording and checklist	1	1, 2 and 4
				3	6, 7
ICT coordinators	Interview	2	Audio recording	1	1, 2 and 4
				3	6, 7
	Professional learning workshop	2	Video recording	2	1 and 4
	Evaluative workshop	2	Video recording	3	5, 6, 7

During stage 1, a contextual analysis of the study area, Ethiopian CTE mathematics teacher educators' current skill in regard to ICT integration into teaching will be performed. This stage explores the existing problems related to mathematics teacher educators understanding of technological pedagogical content knowledge and contextual factors in using technology in learning (e.g. availability of resources, administrative support). In addition, it will identify the professional learning needs of the teacher educators to effectively use technology in their daily teaching learning activities. This stage is mainly aimed at investigating Theme 1, 2, 3 and 4. At this stage, data will be collected through interview, questionnaire, focus group discussion and observation sessions. Interview will be carried out with 10 teacher educators, 10 pre-service teachers and 2 ICT coordinators. A survey questionnaire will be distributed to 120 pre-service teachers and 20 teacher educators. To understand depth and nuances of opinions of participants related to theme 1, 2, 3 and 4, a focus group discussion will be carried out with 6 teacher educators and 6 pre-service teachers. The group setting allows individual participants to use the ideas of others as cues to elicit more their own views fully. Whereas, one-on-one interviews will be used to uncover the best thinking of each and every participant without the drawbacks of group dynamics. Authentic classroom observation in 6 teacher educators' lesson will be done before stage 2 on which each observation will take 50 minutes. The observation will be video recorded as well as journal recording will be used to collect data.

During Stage 2 of the study, exemplary support materials to be used by the teacher educators as a guide to integrating technology into teaching will be produced by the researcher using design principles and through collaboration among teacher educators. The material will assist the teacher educators by suggesting procedurally specific activities and tasks with respect to lesson planning such as lesson preparation, topic, objectives, teacher educators and pre-service teachers' activities, time allotment, assessment techniques etc. while using technology. Before crafting the material, the researcher and members of the department who will participate in the study will be exposed to various important issues of ICT integration into teaching, design principles, and exemplary support materials through a professional learning workshop. This will allow participants to develop insights into ICT integration and the exemplary material will encourage the development of positive beliefs and reactions towards them. This forum will be designed to motivate the participants to try out and use the support material in their actual teaching in the third stage of the study. Hence, a data collected from the workshop will be used for the purpose of theme 4 and 7. The data will be the researcher's reflection on the workshop. This stage is a time where teacher educators gain insight to integrate ICT into their teaching which will last for four consecutive months. During these months, the researcher will have a close contact with teacher educators and ICT coordinators.

In the Stage 3 of the study, the overall impact of the intervention on improving teacher educators' experiences and pre-service teachers learning will be assessed in a summative form. As, this an evaluation stage, all activities carried out at stage 1 will be repeated except three teacher educators from each college involved in the study will be observed two times while teaching ICT integrated lessons and the evaluative workshop will be video recorded. In addition, the interview with teacher educators will be associated with the whole intervention about their experiences and the thoughts they have concerning program operations, processes, and outcomes, and about any changes they perceive in themselves as a result of their involvement in the process.

Finally, the data from questionnaires and observation checklists will be analysed by using means, frequencies, standard deviations, Cohen d effect size and t-test (mean comparison by independent sample test). The statistical package for social sciences (SPSS) program will be employed to calculate the mean, standard deviations and t-test as well as the Cohen d effect size. The Cohen's d effect size analysis will be used to indicate the standardized difference between two means and the magnitude of the effect gained as the result of the intervention activities. Whereas, the qualitative data analysis will be done by grouping and categorizing into clusters that address the same issue and develop meaningful results.

The qualitative data and the quantitative results will be combined and triangulated to make a report more meaningful. Data from different sources will be analysed according to themes. The complete data set will be compared and contrasted in relation to theoretical literatures.

14. Data

Will photographs be taken?	Yes	<input type="checkbox"/>	No	<input checked="" type="checkbox"/>
Will video-recordings be made?	Yes	<input checked="" type="checkbox"/>	No	<input type="checkbox"/>
Will interviews or focus groups be tape-recorded?	Yes	<input checked="" type="checkbox"/>	No	<input type="checkbox"/>

If you answered "Yes" to any of the above, please describe the information to be collected.

For the purpose of the proposed research, focus group discussion interview and video recorded data will be used.

Recorded interview data will be collected from teacher educators, ICT coordinators and pre-service teachers. Whereas, the focus group discussion will be carried out with pre-service teachers and teacher educators. The focus group discussion and the interview is aimed to investigate teacher educators current skill and motivation of using ICT into teaching, explore factors influencing teacher educators to integrate ICT into teaching, investigate pre-service teachers current motivation and interest for ICT integrated lessons, investigate professional needs of teacher educators to integrate ICT into teaching, investigate pre-service teachers' motivation and interest for ICT integrated lessons after intervention activities and investigate teacher educators' skill and motivation to integrate ICT into teaching after/during intervention activities. A one-on-one interview over focus group discussion will be used to uncover the best thinking of each and every participant without the drawbacks of group dynamics.

Video recording will be carried out at two points of the study specifically, i) during teacher educators' practical use of ICT in teaching and ii) during the proposed final evaluative workshop for the same purpose as explained for recoded interview. If one or more pre-service teachers are not interested in the observation session, a separate class will be prepared to observe teacher educators' ICT integrated teaching. This will help the investigator to video record the session so that those pre-service teachers who are not interested in participating in the session will not be included in the recording. In addition, if there is accidental footage of participants who had not consented, it will be edited and cut out.

15. Disclosure and consent:

Does the project collect information from which individual participants can be identified? (NS 2.2)

Yes ☒ No ☐

If yes, could the research be conducted using non-identifiable information?

Yes ☒ No ☐

Does this project use any form of implicit or passive consent? (NS 2.2.5, 2.3)

Yes ☒ No ☐

*If yes, please describe how your research complies with the relevant section of the *National Statement*.*

If participants choose to take part in survey, the completion of the questionnaire will be accepted as formal consent that will be considered as they have understood all of the information concerning that part of the study and are willing to participate in it by contributing survey data. Hence, by completing the survey questionnaire, pre-service teacher and teacher educator participants are granting passive consent. With regard to the National Statement guidelines, the conditions of this study satisfy all the criteria for waiving the need for written consent listed in section 2.2.5. All these will be explained to participants in the information sheet.

Written consent is attached for those participants (teacher educators, pre-service teacher and ICT coordinators) who take part in one or more of the activities which includes interviews, professional learning workshops, focus group discussion, classroom observation and final questionnaire.

Will there be any deception of participations including concealment and covert observation? (NS 2.3.1, 2.3.2)

Yes ☐ No ☒

*If yes, please describe how your research complies with the relevant section of the *National Statement*.*

15. Disclosure and consent - continued . . .

Describe how participants will **consent** to participate in this study and how they will be informed of their rights (NS 2.2.1-2.2.7). Attach copies of your Information Sheet and Consent Form (where relevant) or give an explanation of the process by which you will obtain consent.

(Pro formas for Information Sheets and Consent Forms are available on our website at: http://www.research.utas.edu.au/human_ethics/social_science_forms.htm)

The investigator will not have any contact with proposed participants during information sheet and consent form distribution. As a consequence, the distribution of information sheet and consent form, and collection of signed consent form will be according to the following procedures.

The researcher will contact the initial teacher education colleges after successful approval from the regional education office. The ARVDs will be asked to distribute the information sheet and consent form for teacher educators which invites their willingness to participate in a survey questionnaire. The survey will allow participants to indicate their willingness to participate in one or more of the activities which includes an interview, professional learning workshop, and focus group discussion and observation sessions. Participants who are interested to participate in one or more of them will be invited to provide their phone number or email directly to the researcher by writing it on the survey. As a result, interview, professional learning workshop, focus group discussion and observation session participants will be selected from those who showed their willingness in survey questionnaire. In addition, ARVDs will be asked to distribute the information sheet and consent form for the ICT coordinators to participate in an interview. If the ICT coordinators are interested to participate in an interview, they will be invited for another interview and professional learning workshops participation.

Teacher educators who showed an interest to participate in the research process will be approached to distribute an information sheet and consent form for pre-service teachers. Pre-service teachers who are willing to participate in the study will be asked to fill a survey questionnaire. The survey will allow participants to indicate their willingness to participate in an interview, possible focus group discussion, classroom observations and filling final questionnaire. Participants who choose this option will be asked to provide a contact phone number or email address. The table below shows a summary.

Table 5: Information sheet distribution and signed consent form collection procedure

Participants	Information sheet and consent form distributed and collected by:	Signed consent form forwarded to the researcher by:	Note
Teacher educators	ARVDs	Teacher educators	
Pre-service teachers	Teacher educators	Pre-service teachers	
ICT coordinators	ARVDs	ICT coordinators	

Separate consent form is prepared for the above three groups of participants.

16. Reimbursement

Is any reimbursement, payment, or other reward (outside of course credit) being offered to participants in the study? (NS 2.2.10)

Yes ☒ No ☐

If yes, please state what will be offered, what amount will be offered and for what purpose (e.g. a voucher as a prize, reimbursement to cover expenses etc).

The investigator will reimburse the costs of teacher educator and ICT coordinator participants who will take part in research, including costs such as travel, and accommodation. This is because there will be professional learning workshop for these participants who are located at two different places; one group has to travel to take part in the workshop. In addition, these participants will be appreciated through honorarium for their voluntary participation. The estimated cost of the research at the field is indicated in Table 6.

Table 6 Estimated cost of the research

<i>Purpose</i>	<i>No/Teacher Educator and ICT coordinator Participants</i>	<i>Estimated cost/person (AUD)</i>	<i>Total (AUD)</i>	<i>In Ethiopian Birr</i>	<i>Note</i>
Transportation	11	20	220	3916	One group will travel.
Payment for the time involved	22	25	550	9790	
Coffee/tea	22	10	220	3916	There will be workshop at two different stages
Total			AUD 990	17,622	

Current Ethiopian currency exchange rate is AUD 1 = Birr 17.8 (Ethiopian currency)

The cost will be covered by the fund allocated by the Faculty of Education for PhD research purposes. The payment is proportionate to the time involved and actual cost to participate hence will not encourage participants to participate or take risks.

17. Intrusiveness

Are there any aspects of the study that are intrusive in areas ordinarily considered personal and private, or that could create apprehension and anxiety for participants?

Yes ☐ No ☒

Are you collecting personal details or private information?

Yes ☐ No ☒

Is there any kind of dependency relationship between the researcher and any of the participants?

Yes ☐ No ☒

If you answered "Yes" to any of the above, please explain in more detail.

18. Potential benefits, risks and harms (NS 2.1)

(a) What are the possible benefits of this research to:

(i) The participant?

The study will be an opportunity for teacher educators, pre-service teachers and ICT coordinators to reflect current status of teacher educators ICT integration skills as well as to show future direction. In addition, the study will be part of teacher educators' professional development in ICT integration in teaching

(ii) The wider community?

We hope that the results of this study will

- Serve as reference material for the development of policy issues and provide professional development materials in the field of integrating technology in the teaching learning process in general and in the area of mathematics education in particular.
- Introduce a culture of well-planned in-service professional development to the Ethiopian teacher education college system. It will help Ethiopian CTE administration and other concerned bodies develop favourable attitudes towards the professional development activities of teacher educators.
- Help Ethiopian pre-service mathematics teacher educators to improve their technological, pedagogical and content knowledge and thereby improve their teaching performance and thus enhance pre-service teachers learning.
- Add to the knowledge base of linking mathematics education, professional development and technology integration in teacher education institutes.

(b) What are the possible risks or harms of this research to the participants? (NS 2.1)

Could your research evoke anxiety or lead to the recall of painful memories? Yes ☐ No ☒

Will participants be asked to provide any information or commit any act, which might diminish self-respect or cause them to experience shame, embarrassment or regret? Yes ☐ No ☒

Will any procedure be used which may have an unpleasant or harmful side effect? Yes ☐ No ☒

Does the research use any stimuli, tasks, or procedures, which may be experienced by subjects as stressful, noxious, or unpleasant? (NS 2.1) Yes ☐ No ☒

Will you induce or create physical pain beyond mild discomfort? Yes ☐ No ☒

Are there any other possible risks or harms of this research to the participants? Yes ☐ No ☒

If yes, please list other possible risks or harms.

If you answered yes to any of the above, please describe how your research will comply with the National Statement (2.1). In addition, please describe the process(es) you will use to manage possible risks (e.g. if interviews may cause distress, provide details of support processes that will be put into place).

19. Monitoring

What mechanisms do you intend to implement to monitor the conduct and progress of the research project? (NS 5.5).

The study will be conducted outside Australia (Ethiopia); hence, the investigators will meet regularly throughout the project process via email, Skype and telephone for proper progress reports on the research. If anything occurs that is not anticipated in this ethics application form or there is a need for modification on the research process, the investigator will immediately inform the University research office and will first seek an amendment to the ethics approval for the project. Moreover, in the process, the investigators will submit a progress report to HREC. Finally, a final report will be submitted on the completion of the project, and the HREC will be notified if any adverse incidents occur.

20. Feedback

What feedback will be given to participants?

How will feedback be given? (NS 1.5)

The feedback will be provided in different forms and occasions of the study for teacher educators and ICT coordinators:

- An evaluation workshop will be prepared to evaluate the overall process of the research which includes teacher educators reflection and feedback. Teacher educators and ICT coordinators will be encouraged to reflect on the overall activities of the intervention process. This can be an opportunity to study from each other and obtain feedback for future improvement.
- The draft report of the analysed data will be forwarded to groups of teacher educators and ICT coordinators for feedback. Particularly, this will give an opportunity for teacher educator participants to obtain feedback on their practice of teaching with ICT.
- Each participant will have the opportunity to obtain a transcribed copy of their interview and other informant based data. The participants will be informed to contact the investigators via email or phone so that they are able to obtain a transcribed copy of their interview and other informant based data

Moreover, letter of acknowledgment and thanks will be provided to all participants of the study.

21. Data Storage

Please state how and where your data will be stored, and for how long it will be retained.

Address any issues of data security.

Please note: Data must be stored for at least five years beyond the date of publication and then destroyed.

All data must eventually be destroyed, unless explicit consent has been obtained from the participants to archive their data.

As the data collection will take place in Ethiopia, as soon as the data is available, the video and recorded data will be copied and stored in a personal password protected laptop. Whereas, the paper based data will be kept in a personal locked file cabinet until shipped to Australia. After the data is arrived in Australia, the data will be kept in the secured places. The paper based data, video-tapes and audio-tapes will be kept in locked file cabinets in the Faculty of Education of the University of Tasmania, Newnham Campus. In addition, the digital videos and digital recordings will be kept in a password protected laptop of mine which is provided by the university. The laptop is linked with the university administered network; hence these digital recordings will be also kept in student investigator's a local disk which is more secured. After 5 years, the data will be deleted and audio recordings cleaned as per UTAS guidelines.

22. Other Ethical Issues

Are there in your opinion any other ethical issues involved in the research?

Yes ☐ No ☒

The student researcher is familiar with the research context. He is familiar with the communities and how to engage with them and can therefore conduct the research safely on that environment.

If you answered "Yes", please explain in more detail.

23. Declarations

a) Statement of Scientific Merit:

The Head of School or the Head of Department is required to sign the following statement of scientific merit:

“This proposal has been considered and is sound with regard to its merit and methodology.”

The Head of School's or Head of Department's signature on the application form indicates that he/she has read the application and confirms that it is sound with regard to:

- (i) educational and/or scientific merit; and
- (ii) research design and methodology.

This does not preclude the SSHREC from questioning the research merit or methodology of any proposed project.

If the Head of School is one of the investigators, this statement must be signed by an appropriate person. This may be the Head of School/Department in a related area or the Dean. The certification of scientific merit may not be given by an investigator on the project.

Name

Position

Signature

Date

b) Conformity with the National Statement

The *Chief Investigator* is required to sign the following statement:

I have read and understood the *National Statement on Ethical Conduct in Human Research 2007*. I accept that I, as chief investigator, am responsible for ensuring that the investigation proposed in this form is conducted fully within the conditions laid down in the *National Statement* and any other conditions specified by the HREC (Tasmania) Network.

Name Kim Beswick

Position

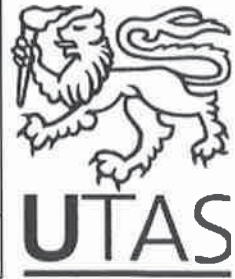
Signature	
Date	16/03/2012

c) Signatures of other investigators I acknowledge my involvement in the project and I accept the role of the above researcher as chief investigator of this study.		
Name: Seyum Tekeher	Signature:	Date: 16/03/2012
Name: Rosemary Callingham	Signature:	Date: 16/03/2012
Name:	Signature:	Date:

CHECKLIST	
Please ensure that the following documents are included with your application:	
Information sheet/s (if not attached ensure you have explained why in Section 10)	<input checked="" type="checkbox"/>
Consent form/s (if not attached ensure you have explained why in Section 15)	<input checked="" type="checkbox"/>
Questionnaires (if applicable)	<input checked="" type="checkbox"/>
Interview schedules (if applicable)	<input checked="" type="checkbox"/>
A copy of any permissions obtained i.e. Other HREC, Other Institutions (if applicable)	<input type="checkbox"/>
All documents relevant to the study, including all information provided to subjects.	<input checked="" type="checkbox"/>
Telephone Preambles (if applicable)	<input type="checkbox"/>
Recruitment Advertisements (if applicable)	<input type="checkbox"/>
Email Contents (if applicable)	<input type="checkbox"/>

<p align="center">TO SUBMIT THIS APPLICATION:</p> <p>1. You must email an electronic copy of this application form (can be unsigned) and all supporting documents to:</p> <p align="center">Katherine.Shaw@utas.edu.au</p> <p align="center">(Please submit as Microsoft Word documents) .pdf versions are acceptable for appropriate documents, eg., posters or advertisements, some questionnaires etc.</p> <p>2. You must <i>also</i> send a signed hard copy of this application form and all supporting documents to Katherine Shaw, Private Bag 1, Hobart, 7001</p>	
Has the 'Statement of Scientific Merit' been signed	<input type="checkbox"/>
Have all investigators signed the form?	<input type="checkbox"/>

Social Science Ethics Officer
Private Bag 01 Hobart
Tasmania 7001 Australia
Tel: (03) 6226 2763
Fax: (03) 6226 7148
Katherine.Shaw@utas.edu.au



HUMAN RESEARCH ETHICS COMMITTEE (TASMANIA) NETWORK

24 May 2012

Assoc Prof Kim Beswick
School of Education
University of Tasmania
Locked Bag 1307
Launceston Tasmania

Student Researcher: Seyum Getenet

Dear Assoc Prof Beswick

Re: FULL ETHICS APPLICATION APPROVAL

Ethics Ref: **H0012436 - Enhancing mathematics teacher educators' technological, pedagogical, and content knowledge through collaborative professional development: Ethiopia**

We are pleased to advise that the Tasmania Social Sciences Human Research Ethics Committee approved the above project on 17 May 2012.

This approval constitutes ethical clearance by the Tasmania Social Sciences Human Research Ethics Committee. The decision and authority to commence the associated research may be dependent on factors beyond the remit of the ethics review process. For example, your research may need ethics clearance from other organisations or review by your research governance coordinator or Head of Department. It is your responsibility to find out if the approval of other bodies or authorities is required. It is recommended that the proposed research should not commence until you have satisfied these requirements.

Please note that this approval is for four years and is conditional upon receipt of an annual Progress Report. Ethics approval for this project will lapse if a Progress Report is not submitted.

The following conditions apply to this approval. Failure to abide by these conditions may result in suspension or discontinuation of approval.

1. It is the responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval, to ensure the project is conducted as approved by the Ethics Committee, and to notify the Committee if any investigators are added to, or cease involvement with, the project.

2. Complaints: If any complaints are received or ethical issues arise during the course of the project, investigators should advise the Executive Officer of the Ethics Committee on 03 6226 7479 or human.ethics@utas.edu.au.
3. Incidents or adverse effects: Investigators should notify the Ethics Committee immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.
4. Amendments to Project: Modifications to the project must not proceed until approval is obtained from the Ethics Committee. Please submit an Amendment Form (available on our website) to notify the Ethics Committee of the proposed modifications.
5. Annual Report: Continued approval for this project is dependent on the submission of a Progress Report by the anniversary date of your approval. You will be sent a courtesy reminder closer to this date. **Failure to submit a Progress Report will mean that ethics approval for this project will lapse.**
6. Final Report: A Final Report and a copy of any published material arising from the project, either in full or abstract, must be provided at the end of the project.

Yours sincerely

Katherine Shaw
Ethics Officer
Tasmania Social Sciences HREC

Appendix B

Support letter from the University of Tasmania, Faculty of education

Date: 14 January 2013

To whom it may Concern

Subject: Assistance in the conduction of field work of Seyum Tekeher

This letter serves to inform you that Mr. Seyum Tekeher is a PhD student at the University of Tasmania, Australia.

Seyum is planning to conduct his PhD study entitled "*Enhancing mathematics teacher educators' technological, pedagogical, and content knowledge through collaborative professional development: Ethiopia*" in the second semester of 2012/2013 in Debere Berhan and Debere Markose teacher education colleges. The study will incorporate professional development, interviews, focus group discussion and survey with mathematics teacher educators, pre-service teachers and ICT coordinators. In addition, it involves the use of ICT resource centers.

It is our hope and strong belief that the Seyum Tekeher's research will contribute to the enhancement of Ethiopian educational quality in general and to that of Debere Berhan and Debre Markose Teachers Colleges.

We therefore kindly ask you to provide Mr, Seyum Tekeher with all possible support needed during his PhD study in the two colleges.

Yours Sincerely,

Professor Ian Hay

Dean, Faculty of Education

University of Tasmania

Appendix C

Support Letter from Amhara Regional State Education office



የአማራ ብሔራዊ ክልላዊ መንግሥት ትምህርት ቢሮ
Amhara National Regional State Education Bureau

ቁጥር ት02/114/አት-18/0.1

ቀን 20/05/2005



ጉዳዩ፡- ለአቶ ስዩም ጥቁሄር ትብብር እንዲደረግለት ስለመጠየቅ፤

አቶ ስዩም ጥቁሄር የፒ.ኤ.ቺዲ (PhD) ጥናቱን በደብረ ብርሃንና በደብረ ማርቆስ ኮሌጆች ለማድረግ ማቀዱን አሳውቆ ትምህርቱን ከሚከታተልበት የንብርሰ.ቲ በተባፈ ደብዳቤ የድጋፍ ደብዳቤ ለኮሌጆቹ እንዲፃፍለት ጠይቆናል።

በመሆኑም የሚሰራው ጥናት ለኮሌጆቹ አልፎም ለሃገሪቱ ከፍተኛ አስተዋፅኦ ስላለው የሚያስፈልገው ትብብር ሁሉ በእናንተ በኩል እንዲደረግለት እየጠየቅን፤ ከሚደረግለት ትብብር መካከል መምህራንና ተማሪዎችን በንቃት እንዲሳተፉ እንዲሁም የኮሌጁን የICT ማዕከል መጠቀም እንዲችል ትብብራችሁ እንዳይለየው በትህትና እንጠይቃለን።

ከሰላምታ ጋር



የብባል አዲስ ጉበኩ
ምክትል ቢሮ ኃላፊ

ግልባጭ፤

- ለአቶ ስዩም ጥቁሄር
ባሉበት፤

ጽሕፈት 058 226 1508

ፋክስ 058 222 0813

Fax 058 222 08 13

ጥራት ያለው ትምህርት ለሁሉም

Quality Education For All

ፖ.ሣ.ቁ 764

☒ P.o.B. 764

Appendix D

Participants' information and consent forms



PARTICIPANT INFORMATION SHEET

Enhancing Mathematics Teacher Educators' Technological, Pedagogical, and Content Knowledge through Collaborative Professional Development: Ethiopia

INFORMATION SHEET FOR TEACHER EDUCATOR PARTICIPANTS

1. Background and Study Overview

I am Seyum Tekeher (Doctoral Student) under the direction of Associate Professor Kim Beswick and Associate Professor Rosemary Callingham in the Faculty of Education at the University of Tasmania, Australia. I am conducting a research study as partial fulfilment of the requirements of a PhD. The study is aimed at investigating the effects of collaborative professional development in enhancing mathematics teacher educators' technological, pedagogical, and content knowledge. Participation in the study involves filling in a questionnaire, participating in interviews and focus group discussions, participating in series of workshops, and having some of your lessons observed.

All mathematics educators at _____ Colleges are being invited to take part in this study. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. Please take time to read the following information carefully. Please ask the investigator if there is anything that is not clear of and if you need more information.

2. Purpose of the study

This study is proposed with the aim of exploring the impact of collaborative professional development on mathematics teacher educators' technological, pedagogical, and content knowledge in Ethiopian initial teacher education colleges. Participants in the study will have an opportunity to learn about and trial integrating technology with their mathematics pedagogy and content as they teach pre-service teachers.

3. Study Procedure

The study will have three stages throughout the process.

Stages	Your activity and involvement
Stage 1: Context Analysis	<ol style="list-style-type: none">1. Filling in an initial survey questionnaire. This will take approximately 20 minutes.2. Participating in an interview which will take 30 minutes.3. Inviting the investigator to observe a lesson.4. Focus group discussion about the use of technology in preservice teacher education for mathematics teaching. This will take 1 hour.
Stage 2: Intervention	<ol style="list-style-type: none">1. Participating in a professional learning workshop about the use of technology in preservice teacher education for mathematics teaching.2. Inviting the investigator to observe a lesson.3. Participating in discussions about effective use of technology with the researcher and colleagues.
Stage 3: Impact assessment	<ol style="list-style-type: none">1. Filling in a final survey questionnaire. This will take approximately 20 minutes.2. Participating in an interview which will take 30 minutes.3. Inviting the investigator to observe a lesson.4. Participating in focus group discussions about the use of technology in preservice teacher education for mathematics teaching. This will take an hour.5. Participating in an evaluative workshop about the use of technology in preservice teacher education for mathematics teaching reflect on the overall process of the intervention.

A survey questionnaire, information sheet and consent form will be forwarded to you by the Academic and Research Vice Dean of the college. At this stage, this information sheet will act as a reference for you. You are encouraged to discuss the consent form and information sheet with the investigator if you have any questions or concerns. The survey will comprise a series of items related to your experiences of integrating ICT into your teaching. You will be asked to indicate the extent of your agreement from 'Strongly Agree' to 'Strongly Disagree'. Furthermore, you will be asked to indicate your gender, age and your experience(s) in teaching. If you choose to take part in this survey, the completion of the questionnaire will be accepted as your formal consent that you have understood all of the information concerning that part of the study and are willing to participate in it by contributing survey data.

At the end of the questionnaire, you will be asked to indicate your willingness to participate in one or more of the additional activities listed in the table above: namely interviews, learning and evaluative workshops, focus group discussions, and lesson observations all related to the issues raised in the questionnaire. In addition, you are advised to write your email or phone number for further follow up at the end of the questionnaire and hand over the completed questionnaire to the investigator at the department of mathematics education. If you choose to be involved in one or more of an interview, learning and evaluative workshops, focus group discussion, lesson observation or filling a final questionnaire, you will be asked to sign a formal 'Statement of Informed Consent'. Signing the consent form will indicate that you have read and understood all of the information concerning the project and is required as evidence of your consent to participate in one, several or all of the activities that are part of this study.

4. Risks

There are no specific risks anticipated from participation in this study. You may decline to participate in any activity or terminate your involvement in the research at any stage and time if you wish. You may request that data you have contributed be withdrawn from the study. If you find that you are becoming distressed or overly concerned, you will be advised to receive support from Support Service of the College at _____ for _____ CTE participants and at +251587714505 for _____ CTE participants.

5. Benefits

The study will be an opportunity for you to reflect on the current status of teacher educators' ICT integration skills, including your own. In addition, the study will be part of your professional development in ICT integration in teaching. Furthermore, we hope that the results of this study will:

- Provide reference material for the development of policy and professional development materials in the field of integrating technology in the teaching learning process in general and in the area of mathematics education in particular.
- Contribute to the introduction of a culture of well-planned in-service professional development to the Ethiopian initial teacher education college system. It will help Ethiopian College of Teacher Education (CTE) administration and other concerned bodies develop favourable attitudes towards the professional development activities of teacher educators.
- Help Ethiopian pre-service mathematics teacher educators improve their technological, pedagogical and content knowledge and thereby improve their teaching and thus enhance pre-service teachers learning.



- Add to the knowledge base of linking mathematics education, professional development and technology integration in initial teacher education institutes.

6. Confidentiality

Your comments, reflection, and responses will be anonymous. In addition, every effort will be made by the researcher to preserve your confidentiality including the following:

- Assigning code names/numbers for participants that will be used on all researcher notes and documents.
- Interview transcriptions, and transcribed notes and any other identifying participant information will be kept in a locked file cabinet in the Faculty of Education of the University of Tasmania, Newnham Campus. In addition, the digital videos and digital recordings will be kept in a password protected laptop of mine which is provided by the university. After five years, all the materials will be destroyed.
- All researchers may review the investigator's collected data. Information from this research will be used solely for the purpose of this study and any publications that may result from this study.
- Video recording will be carried out during observation sessions, professional learning and evaluative workshops. Any, accidental footage of participants who have not consented will be edited and cut out.
- As a research participant, you will have the opportunity to amend your interview and focus group discussion transcripts.
- You should be aware that if you participate in a focus group discussion, although the investigator will maintain confidentiality it is not possible to guarantee that other group members will do so.
- Each participant has the opportunity to obtain a transcribed copy of their interview and other personal informant based data.

7. Person to Contact

Should you have any questions about the research or any related matters, please contact the investigators: Seyum Tekeher at Seyum.Tekeher@utas.edu.au or +61363243792; Kim Beswick at Kim.Beswick@utas.edu.au or +61362267679 and Rosemary Callingham at Rosemary.Callingham@utas.edu.au or +61 3 6324 3051. You are welcome to contact us to discuss any issue related to the research study.

8. Institutional Human Research Ethics Committee

This study has been approved by Tasmanian Social Sciences Human Research Ethics Committee. If you have concerns or complaints about the conduct of this study, please contact the Executive officer of the HREC (Tasmania) Network on +61362267479 or email human.ethics@utas.edu.au. The Executive Officer is the person nominated to receive complaints from research participants. Please quote ethics reference number H1236.

9. Voluntary Participation

Your participation in this study is voluntary. It is up to you to decide whether or not to take part in this study. If you do decide to take part in this study other than the survey, please sign the consent form and send it to the investigator. If you decide not to take part in this study, you are still free to withdraw at any time and stage of the study without giving a reason. In addition, you have the right to ask for your data to be withdrawn from the research if you wish to do so.

10. Costs to You

There are no costs to you for your participation in this study. Reimbursement will be paid for the time involved where appropriate.



The information sheet is for you to keep.

If you wish to take part in one or more additional activities mentioned, please sign the consent form on the next page by ticking your choice(s). Thank you for taking the time to consider this study!



Enhancing Mathematics Teacher Educators' Technological, Pedagogical, and Content Knowledge through Collaborative Professional Development: Ethiopia

STATEMENT OF CONSENT FORM FOR TEACHER EDUCATOR PARTICIPANTS

1. I agree to take part in the research study named above.
2. I understand that the study involves in the following activities: interviews, professional learning workshops, focus group discussions, lesson observations and filling a final questionnaire.
3. I agree to participate in the following activities (please tick on the box on one or more or all of the following):
 - a) interviews ☐
 - b) professional learning workshops ☐
 - c) focus group discussions ☐
 - d) observation sessions ☐
 - e) filling a final questionnaire ☐

The activities will be focused on issues raised in the initial questionnaire

4. I have read and understood the Information Sheet for this study.
5. The nature and possible effects of the study have been explained to me.
6. I understand that there are no specific risks anticipated from participation in this study.
7. I understand that all research data will be securely stored on the in the Faculty of Education of the University of Tasmania, Newnham Campus premises for five years from the publication of the study results, and will then be destroyed.
8. Any questions that I have asked have been answered to my satisfaction.
9. I understand that the researchers will maintain confidentiality and that any information I supply to the researchers will be used only for the purposes of the research.
10. I understand that in the focus group discussion, although the investigator will maintain confidentiality it is not possible to guarantee that other group members will do so
11. I understand that the results of the study will be published in such a way that I cannot be identified as a participant.
12. I understand that my participation is voluntary and that I may withdraw at any time without any effect. If I so wish, I may request that any data I have supplied to date be withdrawn from the research.

Participant's name: _____

Participant's signature: _____ Date in Ethiopia: _____

Email or phone number: _____

Statement by Investigator

☐

I have explained the project and the implications of participation in it to this volunteer and I believe that the consent is informed and that he/she understands the implications of participation.

If the Investigator has not had an opportunity to talk to participants prior to them participating, the following must be ticked.

☐

The participant has received the Information Sheet where my details have been provided so participants have had the opportunity to contact me prior to consenting to participate in this project.

Investigator's name: _____

Investigator's signature: _____ Date: _____



PARTICIPANT INFORMATION SHEET

Enhancing Mathematics Teacher Educators' Technological, Pedagogical, and Content Knowledge through Collaborative Professional Development: Ethiopia

INFORMATION SHEET FOR PRE-SERVICE TEACHER PARTICIPANTS

1. Background and Study Overview

I am Seyum Tekeher (Doctoral Student) under the direction of Associate Professor Kim Beswick and Associate Professor Rosemary Callingham in the Faculty of Education at the University of Tasmania, Australia. I am conducting a research study as partial fulfilment of the requirements of a PhD. The study is aimed at investigating the effects of collaborative professional development in enhancing mathematics teacher educators' technological, pedagogical, and content knowledge. Participation in the study involves filling in a questionnaire, participating in interviews and focus group discussions and having some of your lessons observed.

Pre-service mathematics teachers at _____ and _____ Colleges are being invited to take part in this study. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. Please take time to read the following information carefully. Please ask the investigator if there is anything that is not clear of and if you need more information.

2. Purpose of the study

This study is proposed with the aim of exploring the impact of collaborative professional development on mathematics teacher educators' technological, pedagogical, and content knowledge in Ethiopian initial teacher education colleges. Participants in the study will have an opportunity to reflect on your experience of learning with technology and teacher educators' skill of integrating technology in teaching mathematics and their effort to integrate technology with their mathematics pedagogy and content as they teach pre-service teachers.

3. Study Procedure

The study will have three stages throughout the process.

Stages	Your activity and involvement
Stage 1: Context Analysis	1. Filling in an initial survey questionnaire. This will take approximately 20 minutes. 2. Participating in an interview which will take 30 minutes 3. Inviting the investigator to observe three lessons
Stage 2: Intervention	1. Inviting the investigator to observe your three lessons.
Stage 3: Impact assessment	1. Filling in a final survey questionnaire. This will take approximately 20 minutes. 2. Participating in an interview which will take 30 minutes 3. Inviting the investigator to observe three lessons. 4. Participating in focus group discussions about teacher educators' use of ICT in teaching mathematics. This will take an hour.

A survey questionnaire, information sheet and consent form will be forwarded to you by mathematics teacher educators. At this stage, this information sheet and the consent form will act as a reference for you. You are encouraged to discuss the consent form and information sheet with the investigator if you have any questions or concerns. The questionnaire will comprise a series of



questions related to your experiences of learning with ICT integrated lessons and teacher educators habit of teaching with ICT. You will be asked to indicate the extent of your agreement from 'Strongly Agree' to 'Strongly Disagree'. Furthermore, you will be asked to indicate your gender, age, year level and your experience(s) in teaching. If you choose to take part in this study, participating in the survey will be accepted as your formal consent that you have understood all of the information concerning that part of the study and are willing to participate in it by contributing survey data.

At the end of the survey, you will be asked to indicate your willingness to participate in one or more of the additional activities listed in the table above: namely interviews, focus group discussions, lesson observations and filling a final questionnaire all related to the issues raised in the initial interview. In addition, you are advised to write your email or phone number for further follow up at the end of the questionnaire and hand over the completed questionnaire to the investigator at the department of mathematics education. If you choose to be involved in one or more of an interview, focus group discussion, lesson observation and filling a final questionnaire, you will be asked to sign on a formal 'Statement of Informed Consent'. Signing the consent form will indicate that you have read and understood all of the information concerning the project and is required as evidence of your consent to participate in one, several or all of the activities that are part of this study. As few pre-service teachers are required to participate in focus group discussion and interview activities, you should be aware that showing an interest to participate in focus group discussion and interview is not a guarantee to participate in these activities.

4. Risks

There are no specific risks anticipated from participation in this study. You may decline to participate in any activity or terminate your involvement in the research at any stage and time if you wish. You may request that data you have contributed be withdrawn from the study. . If you find that you are becoming distressed or overly concerned, you will be advised to receive support from Support Service of the College at _____ for _____ CTE participants and at + _____ for _____ CTE participants.

5. Benefits

The study will be an opportunity for you to reflect on the current status of teacher educators' ICT integration skills, including your experience of learning with ICT. Furthermore, we hope that the results of this study will:

- Provide reference material for the development of policy and professional development materials in the field of integrating technology in the teaching learning process in general and in the area of mathematics education in particular.
- Contribute to the introduction of a culture of well-planned in-service professional development to the Ethiopian initial teacher education college system. It will help Ethiopian College of Teacher Education (CTE) administration and other concerned bodies develop favourable attitudes towards the professional development activities of teacher educators.
- Help Ethiopian pre-service mathematics teacher educators improve their technological, pedagogical and content knowledge and thereby improve their teaching and thus enhance pre-service teachers learning.
- Add to the knowledge base of linking mathematics education, professional development and technology integration in initial teacher education institutes.



6. Confidentiality

Your comments, reflection, and responses will be anonymous. In addition, every effort will be made by the researcher to preserve your confidentiality including the following:

- Assigning code names/numbers for participants that will be used on all researcher notes and documents.
- Interview transcriptions, and transcribed notes and any other identifying participant information will be kept in a locked file cabinet in the Faculty of Education of the University of Tasmania, Newnham Campus. In addition, the digital videos and digital recordings will be kept in a password protected laptop of mine which is provided by the university. After five years, all the materials will be destroyed.
- All researchers may review the investigator's collected data. Information from this research will be used solely for the purpose of this study and any publications that may result from this study.
- Video recording will be carried out during observation sessions. Any accidental footage of the participants who have not consented will be edited and cut out.
- As a research participant, you will have the opportunity to amend your interview and focus group discussion transcripts.
- You should be aware that if you participate in a focus group discussion, although the investigator will maintain confidentiality it is not possible to guarantee that other group members will do so.
- Each participant has the opportunity to obtain a transcribed copy of their interview and other personal informant based data.

7. Person to Contact

Should you have any questions about the research or any related matters, please contact the investigators: Seyum Tekeher at Seyum.Tekeher@utas.edu.au or +6102271682; Kim Beswick at Kim.Beswick@utas.edu.au or +61362267679 and Rosemary Callingham at Rosemary.Callingham@utas.edu.au or +61 3 6324 3051.

8. Institutional Human Research Ethics Committee

This study has been approved by Tasmanian Social Sciences Human Research Ethics Committee. If you have concerns or complaints about the conduct of this study, please contact the Executive officer of the HREC (Tasmania) Network on +61362267479 or email human.ethics@utas.edu.au. The Executive Officer is the person nominated to receive complaints from research participants. Please quote ethics reference number H1236.

9. Voluntary Participation

Your participation in this study is voluntary. It is up to you to decide whether or not to take part in this study. If you do decide to take part in this study other than the survey, please sign the consent form and send it to the investigator. If you decide not to take part in this study, you are still free to withdraw at any time and stage of the study without giving a reason. In addition, you have the right to ask for your data to be withdrawn from the research if you wish to do so.

10. Costs to You

There are no costs to you for your participation in this study. Reimbursement will be paid for the time involved where appropriate.

The information sheet is for you to keep.

If you wish to take part in one or more additional activities mentioned, please sign the consent form on the next page by ticking your choice(s). Thank you for taking the time to consider this study!



Enhancing Mathematics Teacher Educators' Technological, Pedagogical, and Content Knowledge through Collaborative Professional Development: Ethiopia
STATEMENT OF CONSENT FORM FOR PRE-SERVICE TEACHER PARTICIPANTS

1. I agree to take part in the research study named above.
2. I understand that the study involves in the following activities: interviews, focus group discussions, lesson observations and filling a final questionnaire.
3. I agree to participate in the following activities (you can tick all the boxes):
 - a) interviews ☐
 - b) focus group discussions ☐
 - c) observation sessions ☐
 - d) filling a final questionnaire ☐

The activities will be focused on issues raised in the initial questionnaire

4. I have read and understood the Information Sheet for this study.
5. The nature and possible effects of the study have been explained to me.
6. I understand that there are no specific risks anticipated from participation in this study.
7. I understand that all research data will be securely stored on the in the Faculty of Education of the University of Tasmania, Newnham Campus premises for five years from the publication of the study results, and will then be destroyed.
8. Any questions that I have asked have been answered to my satisfaction.
9. I understand that the researchers will maintain confidentiality and that any information I supply to the researchers will be used only for the purposes of the research.
10. I understand that in the focus group discussion, although the investigator will maintain confidentiality it is not possible to guarantee that other group members will do so.
11. I understand that the results of the study will be published in such a way that I cannot be identified as a participant.
12. I understand that my participation is voluntary and that I may withdraw at any time without any effect. If I so wish, I may request that any data I have supplied to date be withdrawn from the research.

Participant's name: _____

Participant's signature: _____ Date in Ethiopia: _____

Email or phone number: _____

Statement by Investigator

☐

I have explained the project and the implications of participation in it to this volunteer and I believe that the consent is informed and that he/she understands the implications of participation.

If the Investigator has not had an opportunity to talk to participants prior to them participating, the following must be ticked.

☐

The participant has received the Information Sheet where my details have been provided so participants have had the opportunity to contact me prior to consenting to participate in this project.

Investigator's name: _____

Investigator's signature: _____ Date: _____



PARTICIPANT INFORMATION SHEET

Enhancing Mathematics Teacher Educators' Technological, Pedagogical, and Content Knowledge through Collaborative Professional Development: Ethiopia

INFORMATION SHEET FOR ICT COORDINATOR PARTICIPANTS

1. Background and Study Overview

I am Seyum Tekeher (Doctoral Student) under the direction of Associate Professor Kim Beswick and Associate Professor Rosemary Callingham in the Faculty of Education at the University of Tasmania, Australia. I am conducting a research study as partial fulfilment of the requirements of a PhD. The study is aimed at investigating the effects of collaborative professional development in enhancing mathematics teacher educators' technological, pedagogical, and content knowledge. Participation in the study involves interviews and professional learning workshops.

ICT coordinators at _____ and _____ Colleges are being invited to take part in this study. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. Please take time to read the following information carefully. Please ask the investigator if there is anything that is not clear of and if you need more information.

2. Purpose of the study

This study is proposed with the aim of exploring the impact of collaborative professional development on mathematics teacher educators' technological, pedagogical, and content knowledge in Ethiopian initial teacher education colleges. Participants in the study will have an opportunity to reflect on mathematics educators' skill of integrating technology with their mathematics pedagogy and content as they teach pre-service teachers.

3. Study Procedure

The study will have three stages throughout the process.

Stages	Your activity and involvement
Stage 1: Context Analysis	Participating in an interview which will take 30 minutes.
Stage 2: Intervention	Participating in a professional learning workshop about the use of technology in pre-service teacher education for mathematics teaching.
Stage 3: Impact assessment	1. Participating in an interview which will take 30 minutes. 2. Participating in an evaluative workshop about the use of technology in pre-service teacher education for mathematics teaching and reflect on the overall process of the intervention.

An information sheet and consent form will be forwarded to you by the Academic and Research vice Dean of the college. At this stage, this information sheet and the consent form will act as a reference for you. You are encouraged to discuss the consent form and information sheet with the investigator if you have any questions or concerns. The interview will comprise a series questions related to your experiences of mathematics teacher educators' skill of integrating

ICT into their teaching. In addition, you will be asked to mention related factors influencing teacher educators' habit of integrating ICT into their teaching. If you choose to take part in the interview will be asked to sign a consent form. In the consent form, you will be asked to indicate your willingness to participate in one or more of the additional activities listed in the table above: namely final interview and learning and evaluative workshops all related to the issues raised in the interview. Signing the consent form will indicate that you have read and understood all of the information concerning the project and is required as evidence of your consent to participate in one or/and both of the activities that are part of this study.

4. Risks

There are no specific risks anticipated from participation in this study. You may decline to participate in any activity or terminate your involvement in the research at any stage and time if you wish. You may request that data you have contributed be withdrawn from the study. If you find that you are becoming distressed or overly concerned, you will be advised to receive support from Support Service of the College at _____ for _____ CTE participants and at _____ CTE participants.

5. Benefits

The study will be an opportunity for you to reflect on the current status of mathematics teacher educators' ICT integration skills and suggest future direction. In addition, the study will be part of your professional development in ICT integration in teaching. Furthermore, we hope that the results of this study will:

- Provide reference material for the development of policy and professional development materials in the field of integrating technology in the teaching learning process in general and in the area of mathematics education in particular.
- Contribute to the introduction of a culture of well-planned in-service professional development to the Ethiopian initial teacher education college system. It will help Ethiopian College of Teacher Education (CTE) administration and other concerned bodies develop favourable attitudes towards the professional development activities of teacher educators.
- Help Ethiopian pre-service mathematics teacher educators improve their technological, pedagogical and content knowledge and thereby improve their teaching and thus enhance pre-service teachers learning.
- Add to the knowledge base of linking mathematics education, professional development and technology integration in initial teacher education institutes.

6. Confidentiality

Your comments, reflection, and responses will be anonymous. In addition, every effort will be made by the researcher to preserve your confidentiality including the following:

- Assigning code names/numbers for participants that will be used on all researcher notes and documents.
- Interview transcriptions, and transcribed notes and any other identifying participant information will be kept in a locked file cabinet in the Faculty of Education of the University of Tasmania, Newnham Campus. In addition, the digital videos and



digital recordings will be kept in a password protected laptop of mine which is provided by the university. After five years, all the materials will be destroyed.

- All researchers may review the investigator's collected data. Information from this research will be used solely for the purpose of this study and any publications that may result from this study.
- Video recording will be carried out during professional learning and evaluative workshops. Any accidental footage of the participants who had not consented will be edited and cut out.
- As a research participant, you will have the opportunity to amend your interview transcripts.
- Each participant has the opportunity to obtain a transcribed copy of their interview and other personal informant based data.

7. Person to Contact

Should you have any questions about the research or any related matters, please contact the investigators: Seyum Tekeher at Seyum.Tekeher@utas.edu.au or +61363243792; Kim Beswick at Kim.Beswick@utas.edu.au or +61362267679 and Rosemary Callingham at Rosemary.Callingham@utas.edu.au or +613 6324 3051. You are welcome to contact us to discuss any issue related to the research study.

8. Institutional Human Research Ethics Committee

This study has been approved by Tasmanian Social Sciences Human Research Ethics Committee. If you have concerns or complaints about the conduct of this study, please contact the Executive officer of the HREC (Tasmania) Network on +61362267479 or email human.ethics@utas.edu.au. The Executive Officer is the person nominated to receive complaints from research participants. Please quote ethics reference number H1236.

9. Voluntary Participation

Your participation in this study is voluntary. It is up to you to decide whether or not to take part in this study. If you do decide to take part in this study, please sign the consent form and send it to the investigator. If you decide not to take part in this study, you are still free to withdraw at any time and stage of the study without giving a reason. In addition, you have the right to ask for your data to be withdrawn from the research if you wish to do so.

10. Costs to You

There are no costs to you for your participation in this study.

The information sheet is for you to keep.

If you wish to take part in one or more additional activities mentioned, please sign the consent form on the next page by ticking your choice(s).

Thank you for taking the time to consider this study!



Enhancing Mathematics Teacher Educators' Technological, Pedagogical, and Content Knowledge through Collaborative Professional Development: Ethiopia

CONSENT FORM FOR ICT COORDINATOR PARTICIPANTS

1. I agree to take part in the research study named above.
2. I understand that the study involves in the following activities: interviews and professional learning workshops.
3. I agree to participate in the following activities (you can tick both boxes):
 - a) interviews ☐
 - b) professional learning workshops ☐

The activities will be focused on issues raised in the initial interview.

4. I have read and understood the Information Sheet for this study.
5. The nature and possible effects of the study have been explained to me.
6. I understand that there are no specific risks anticipated from participation in this study.
7. I understand that all research data will be securely stored on the in the Faculty of Education of the University of Tasmania, Newnham Campus premises for five years from the publication of the study results, and will then be destroyed.
8. Any questions that I have asked have been answered to my satisfaction.
9. I understand that the researchers will maintain confidentiality and that any information I supply to the researchers will be used only for the purposes of the research.
10. I understand that the results of the study will be published so that I cannot be identified as a participant.
11. I understand that my participation is voluntary and that I may withdraw at any time without any effect. If I so wish, may request that any data I have supplied to date be withdrawn from the research.

Participant's name: _____

Participant's signature: _____ Date in Ethiopia: _____

Email or phone number: _____

Statement by Investigator

☐

I have explained the project and the implications of participation in it to this volunteer and I believe that the consent is informed and that he/she understands the implications of participation.

If the Investigator has not had an opportunity to talk to participants prior to them participating, the following must be ticked.

☐

The participant has received the Information Sheet where my details have been provided so participants have had the opportunity to contact me prior to consenting to participate in this project.

Investigator's name: _____

Investigator's signature: _____ Date: _____

Appendix E

Initial questionnaire for teacher educators



QUESTIONNAIRE FOR TEACHER EDUCATORS

The questionnaire is prepared to collect information concerning Ethiopian mathematics teacher educators' skill in technology use, technology integration into teaching.

Please answer each question to the best of your knowledge. Your thoughtfulness and candid responses will be greatly appreciated. Your individual name or identification number will not at any time be associated with your responses. Your responses will be kept completely confidential.

Note: Technology for this study refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc.

Thank you for taking time to complete this questionnaire!

A. Demographic information

1. Campus based

- a. _____
- b. _____

2. Gender

- a. Female
- b. Male

3. Age range

- a. 24-28
- b. 29-33
- c. 34-38
- d. 38+

4. How many years have you taught in

i) Primary school

- a. 0
- b. 1 - 5
- c. 6 - 10
- d. 11 - 15
- e. Above 15

ii) Secondary School

- a. 0
- b. 1 - 5
- c. 6 - 10
- d. 11 - 15
- e. Above 15

iii) Teacher education college

- a. less than 1
- b. 1 - 5
- c. 6 - 10
- d. 11 - 15
- e. Above 15

5. Do you have your own computer in an office at the college? Check all that apply.

- a. Desktop computer Yes No
- b. Laptop Yes No
- c. No, I don't have either

6. How do you access computer and internet? Check all that apply.

- a. No access
- b. Public/ shared computer
- c. Home
- d. Internet Cafe
- e. Other please specify _____

7. How do you rate the importance your department places on the relevance of technology in teaching? (Tick one).

- a. No importance ☐
- b. Some importance ☐
- c. Great importance ☐
- d. Very great importance ☐

8. From your experience of teaching with technology what conclusion can you draw about technology in teaching? (Tick one).

- a) Technology makes no contribution to learning ☐
- b) Technology makes little contribution to learning ☐
- c) Technology makes a high contribution to learning ☐
- d) Technology makes a very high contribution to learning ☐

B. General Technology use and availability

In the following questions, check (X) in the appropriate box in accordance to the level of the technology use in your teaching

1. How available are each of the following types of ICT for your teaching?

	Not available	Limited access	Are not accessible for teaching purpose	Free Access
Personal computers (PC)				
Laptops				
Audio equipment's (e.g. Radio, CD players, Mp3)				
Digital Photo camera				
Mobile Phone				
Data Projector Systems				
Television				

Please specify on the space provided below if there are technology equipment other than listed above and how available.

2. How often do use the following ICT in your teaching?

	Never	Once or twice per semester	About once every month	At least once per week
Personal Computers (Computer Lab)				
Laptops				
Audio equipment's (e.g. Radio, CD players, Mp3)				
Digital Photo cameras				
Mobile phones				
Data Projection systems				
Television				

Please list in the space provided below any of ICT equipment other than listed above and indicate how often you use it.

3. How accessible are the following learning resources/tools for your teaching?

	Not available	Limited access	Are not accessible for teaching purpose	Free Access
Social Media				
YouTube				
Weblogs				
Social learning communities (Facebook, blogs, netlog, fourm etc.)				
Search engines like Google				
Email				
Chat rooms				
Software				
GeoGebra				
Microsoft mathematics				
Spreadsheets				
Power point slides				

Please specify on the space provided below if there are accessible learning resources, software and social media other than listed above and indicate how accessible they are.

4. How often have you used the following learning resources/tools in your teaching?

	Never	Once or twice per semester	About once every month	At least once per week
Social Media				
YouTube				
Weblogs				
Social learning communities (Facebook, blogs, netlog, forum etc.)				
Search engines like Google				
Email				
Chat rooms				
Software				
GeoGebra				
Microsoft mathematics				
Spreadsheets				
Power point slides				

Others please list below and indicate how often

C. Teacher Educators Specialised Technological Pedagogical and Mathematics Knowledge

Technology is a broad concept that can mean a lot of different things. For the purpose of this study, technology refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc. Please answer all of the questions by choosing the most appropriate.

SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree

	SD	D	U	A	SA
TK (Technology Knowledge)					
1. I know how to solve my own technical problems.					
2. I can learn technology easily.					
3. I keep up with important new technologies.					
4. I frequently play with technologies					
5. I know about many different technologies.					
6. I have the technical skills I need to use technologies.					
7. I have had sufficient opportunities to work with different technologies.					
SMK (Specialised Mathematics Knowledge)					
8. I have sufficient knowledge about mathematics.					
9. I can use a mathematical way of thinking.					
10. I have various ways of developing my understanding of mathematics.					
11. I have a mathematical knowledge unique to teaching.					
12. I understand the difference between the knowledge required for teaching mathematics and common knowledge for mathematics.					

SPK (Specialised Pedagogical Knowledge)					
13. I know how to assess pre-service teachers' performance in a classroom.					
14. I can adapt my teaching based-upon what pre-service teachers currently understand.					
15. I can adapt my teaching style to different learners.					

16. I can assess pre-service teachers' learning in multiple ways.					
17. I can use a wide range of teaching approaches in a classroom setting.					
18. I am familiar with pre-service teachers' common misconceptions.					
19. I know how to manage a classroom.					

SPMK (Specialised Pedagogical Mathematics Knowledge)					
20. I can select effective teaching approaches to guide pre-service teachers' thinking and learning in mathematics.					
21. I can use a wide range of teaching approaches to teach mathematics.					
22. I can solve pre-service teachers' mathematical misconceptions using appropriate pedagogy/teaching.					
23. I can anticipate what pre-service teachers are likely to think and choose appropriate teaching approaches.					
24. I can anticipate mathematical concepts that pre-service teachers will find confusing.					
25. I can prevent pre-service teachers learning difficulties with appropriate teaching method.					
STMK (Specialised Technological Mathematics Knowledge)					
26. I know about technologies that I can use to develop pre-service teachers' understanding of mathematics.					
27. I can use a wide range of technologies to teach mathematics.					
28. I can select technologies to use in my classroom that enhance what I teach.					
29. I can't think of teaching mathematics without the use of technology.					
30. I know how to cement the knowledge needed to teach mathematics with the application of technologies.					

STPK (Specialised Technological Pedagogical Knowledge)					
31. I can choose technologies that enhance the teaching approaches for a lesson.					
32. I can choose technologies that enhance pre-service teachers' learning for a lesson.					

33. Teaching pre-service teachers has caused me to think more deeply about how technology could influence the teaching approaches I use.					
34. I think critically about how to use technology in my classroom.					
35. I can adapt the use of the technologies to different teaching activities.					
36. I can select technologies that enhance how I teach.					

STAMPK (Specialised Technology Pedagogy and Mathematics Knowledge)					
37. I can teach lessons that appropriately combine mathematics content, technologies and teaching approaches.					
38. I can choose technology to use in my classroom that enhances what I teach, how I teach and what pre-service teachers can learn.					
39. I can use strategies that combine mathematics content, technologies and teaching approaches.					
40. I can provide leadership in helping others to teach ICT integrated mathematics with teaching approaches.					
41. I can understand pre-service teachers' misconceptions about mathematics concepts and can solve the misconceptions through the application of technology which fit with a selected pedagogy.					

Please describe below your mathematics teaching experiences with technology which can explain one or more of the above questions (questions 37 – 41).

D. Select one level of agreement for each statement to indicate how you feel.

SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree

	I feel confident that I could...	SD	D	U	A	SA
1	Send an e-mail to a friend.					
2	Subscribe to a discussion list.					
3	Create a "nickname" or an "alias" to send e-mail to several people at once.					
4	Send a document as an attachment to an e-mail message.					
5	Keep copies of outgoing messages that I send to others.					
6	Use an Internet search engine (e.g., google, wiki etc) to find Web pages related to mathematical concepts.					
7	Search for and find information in different Web sites.					
8	Create my own World Wide Web home page.					
9	Keep track of Web sites I have visited so that I can return to them later. (An example is using bookmarks).					
10	Find primary sources of information on the Internet that I can use in teaching mathematics.					
11	Use a spreadsheet in teaching mathematics like geometry.					
12	Use Microsoft mathematics in teaching mathematics like graph of quadratic equation.					
13	Use GeoGebra in teaching mathematics like geometry.					
14	Use multiple mathematical software in teaching mathematical concept.					
15	Save documents in formats so that others can read them if they have different word processing programs (e.g., saving Word, ClarisWorks, RTF, or text).					
16	Use the computer to create a slideshow presentation.					
17	Create a database of information about important authors in a subject matter field.					
18	Create a lesson or unit that incorporates subject matter software as an integral part.					
19	Use technology to collaborate with other interns, teacher educators, or pre-service teachers who are distant from my classroom.					
20	Describe different software programs that I would use in my teaching.					
21	Write a plan with a budget to buy technology for my classroom.					

E. Please complete this section by writing your responses.

1. Describe a specific lesson episode where you were effectively demonstrated combining content, technologies, and teaching approaches in a classroom lesson. Please include in your description what content you taught, what technology used, and what teaching approach (es) you implemented.

2. In your opinion, what are the challenges to use technology into your teaching of pre-service teachers?

3. Is there any technological support available for you as teacher educator at the college to help you in integrating technology in your teaching?
If available please describes the kind of support provided?

If not available please list the possible reasons

4. What kind of professional learning workshops or other learning activities about the pedagogical use of ICT are provided to you by the college or other institution(s)?

5. In your opinion, what kind of professional development should be provided to support you to integrate ICT in the teaching of mathematics?

6. What do you know about the Technological, Pedagogical and Content Knowledge (TPACK) framework?

7. What advice would you give to a new colleague about integrating technology into their teaching of mathematics?

8. Any additional comments?



I am interested in participating in the following activities about using technology in pre-service teacher education (you can choose more than one):

- i. An interview ☐
- ii. Professional learning Workshops ☐
- iii. A Focus group discussion ☐
- iv. Observation Sessions ☐

If you choose to participate among one or more of the above, please provide your phone number or email: _____

Thank you!

Appendix F

Final questionnaire for teacher educators



QUESTIONNAIRE FOR TEACHER EDUCATORS

The questionnaire is prepared to collect information concerning Ethiopian mathematics teacher educators' skill in technology use, technology integration into teaching and knowledge on Technological Pedagogical Content Knowledge (TPACK).

Please answer each question to the best of your knowledge. Your thoughtfulness and candid responses will be greatly appreciated. Your individual name or identification number will not at any time be associated with your responses. Your responses will be kept completely confidential.

Note: Technology for this study refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs (e.g., Microsoft Mathematics, GeoGebra, Cabri 3D) etc.

Thank you for taking time to complete this questionnaire!

A. Demographic information

1. Campus based

a. _____ ☐

b. _____ ☐

2. Gender

a. Female ☐

b. Male ☐

3. Age range

a. 24-28 ☐

b. 29-33 ☐

c. 34-38 ☐

d. 38+ ☐

B. General Technology use

In the following questions, check (X) in the appropriate box in accordance to the level of the technology use in your teaching

1. How often do use the following ICT in your teaching?

	Never	Once or twice per semester	About once every month	At least once per week
Personal Computers (Computer Lab)				
Laptops				
Audio equipment's (e.g. Radio, CD players, Mp3)				
Digital Photo cameras				
Mobile phones				
Data Projection systems				
Television				

Please list in the space provided below any of ICT equipment other than listed above and indicate how often you use it.

2. How often have you used the following learning resources/tools in your teaching?

	Never	Once or twice per semester	About once every month	At least once per week
Social Media				
YouTube				
Weblogs				
Social learning communities (Facebook, blogs, netlog, forum etc.)				
Search engines like Google				
Email				
Chat rooms				
Software				
GeoGebra				
Microsoft mathematics				
Spreadsheets				
Power point slides				

Others please list below and indicate how often

C. Teacher Educators Specialised Technological Pedagogical Mathematics Knowledge

Technology is a broad concept that can mean a lot of different things. For the purpose of this study, technology refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc. Please answer all of the questions by choosing the most appropriate.

SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree

	SD	D	U	A	SA
TK (Technology Knowledge)					
1. I know how to solve my own technical problems.					
2. I can learn technology easily.					
3. I keep up with important new technologies.					
4. I frequently play with technologies					
5. I know about a lot of different technologies.					
6. I have the technical skills I need to use technologies.					
7. I have had sufficient opportunities to work with different technologies.					
CK (Mathematics Knowledge)					
8. I have sufficient knowledge about mathematics.					
9. I can use a mathematical way of thinking.					
10. I have various ways of developing my understanding of mathematics.					
11. I have a mathematical knowledge unique to teaching.					
12. I understand the difference between the knowledge required for teaching mathematics and common knowledge for mathematics.					

SPK (Specialised Pedagogical Knowledge)					
13. I know how to assess pre-service teachers' performance in a classroom.					
14. I can adapt my teaching based-upon what pre-service teachers currently understand.					
15. I can adapt my teaching style to different learners.					

16. I can assess pre-service teachers' learning in multiple ways.					
17. I can use a wide range of teaching approaches in a classroom setting.					
18. I am familiar with pre-service teachers' common misconceptions.					
19. I know how to manage a classroom.					

SPMK (Specialised Pedagogical Mathematics Knowledge)					
20. I can select effective teaching approaches to guide pre-service teachers' thinking and learning in mathematics.					
21. I can use a wide range of teaching approaches to teach mathematics.					
22. I can solve pre-service teachers' mathematical misconceptions using appropriate pedagogy/teaching.					
23. I can anticipate what pre-service teachers are likely to think and choose appropriate teaching approaches.					
24. I can anticipate mathematical concepts that pre-service teachers will find confusing.					
25. I can prevent pre-service teachers learning difficulties with appropriate teaching method.					
STMK (Specialised Technological Mathematics Knowledge)					
26. I know about technologies that I can use to develop pre-service teachers' understanding of mathematics.					
27. I can use a wide range of technologies to teach mathematics.					
28. I can select technologies to use in my classroom that enhance what I teach.					
29. I can't think of teaching mathematics without the use of technology.					
30. I know how to cement the knowledge needed to teach mathematics with the application of technologies.					

STPK (Specialised Technological Pedagogical Knowledge)					
31. I can choose technologies that enhance the teaching approaches for a lesson.					
32. I can choose technologies that enhance pre-service teachers' learning for a lesson.					

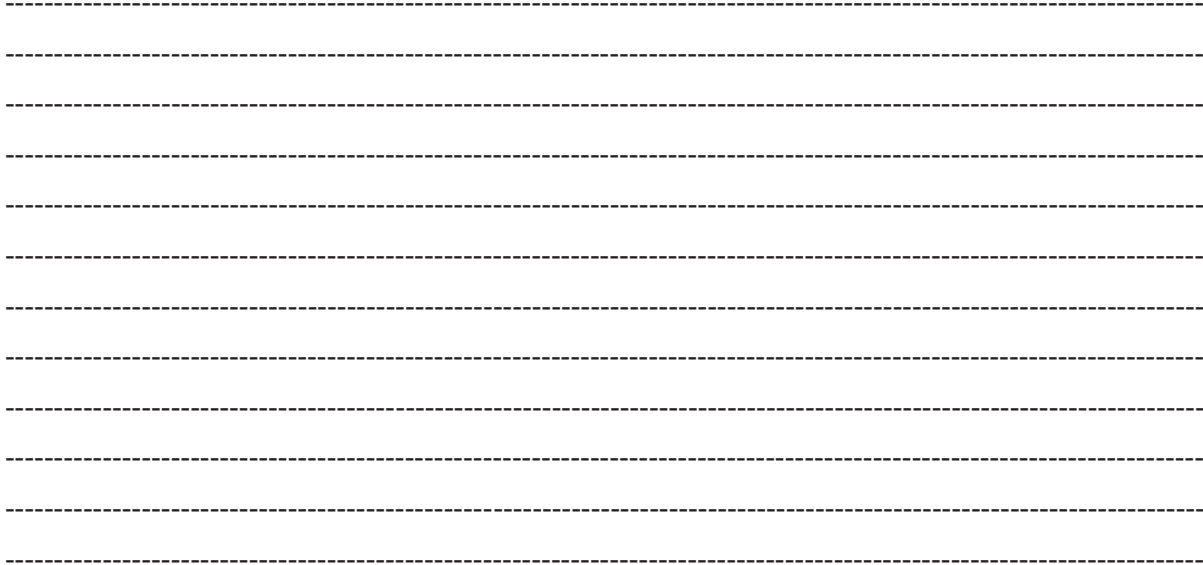
33. Teaching pre-service teachers has caused me to think more deeply about how technology could influence the teaching approaches I use.					
34. I think critically about how to use technology in my classroom.					
35. I can adapt the use of the technologies to different teaching activities.					
36. I can select technologies that enhance how I teach.					

STAMPK (Specialised Technology and Pedagogy Mathematics Knowledge)					
37. I can teach lessons that appropriately combine mathematics content, technologies and teaching approaches.					
38. I can choose technology to use in my classroom that enhances what I teach, how I teach and what pre-service teachers can learn.					
39. I can use strategies that combine mathematics content, technologies and teaching approaches.					
40. I can provide leadership in helping others to teach ICT integrated mathematics with teaching approaches.					
41. I can understand pre-service teachers' misconceptions about mathematics concepts and can solve the misconceptions through the application of technology which fit with a selected pedagogy.					

Please describe below your mathematics teaching experiences with technology which can explain one or more of the above questions (questions 37 – 41).

D. Please complete this section by writing your responses.

1. Describe a specific lesson episode where you were effectively demonstrated/planned combining content, technologies, and teaching approaches in a classroom lesson. Please include in your description what content you taught, what technology used, and what teaching approach (es) you implemented.



-
-
-
-
-
-

- [illegible]

6

Appendix G

Initial questionnaire for pre-service teachers



QUESTIONNAIRE FOR PRE-SERVICE TEACHERS

The questionnaire is prepared to pre-service teacher to collect your opinion concerning technology integration in the teaching learning process of your current teacher education. The questions invite you to reflect on your habit of using ICT while learning. In addition, it invites you to reflect your opinions concerning your mathematics teacher educators' skill and habit of technology integration in their teaching.

Please answer each question to the best of your knowledge. Your thoughtfulness and candid responses will be greatly appreciated. Your individual name or identification number will not at any time be associated with your responses. Your responses will be kept completely confidential.

Note: Technology for this study refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc.

Thank you for taking time to complete this questionnaire!

A. Demographic information

1. Campus attending

a. _____

b. _____

2. Gender

a. Female

b. Male

3. Age range

a. 18-22

b. 23-26

c. 27-32

d. 32+

4. Do you have teaching experience?

a. Yes

b. No

5. If your answer for question 4 above is "yes", how many years of teaching experience do you have?

a. 0 - 5

b. 6-10

c. 11- 15

d. Above 15



6. Year in the college

a. First year

b. Second year

B. General Technology use and availability

In the following questions, check (X) in the appropriate box in accordance to the level of the technology use in the teaching learning process mathematics.

1. How available are each of the following technological equipment for you as a pre-service teacher at the college to facilitate learning?

	Not available	Limited access	Are not accessible for teaching purpose	Free Access
Personal computers (PC)				
Laptops				
Audio equipment's (e.g. Radio, CD players, Mp3)				
Digital Photo camera				
Mobile Phone				
Data Projector Systems				
Television				

Please list on the space provided below and indicate how they are available

2. How often have used the following technological devices while learning mathematics?

	Never	Once twice or per semester	About once every month	At least once per week
Personal Computers (Computer Lab)				
Laptops				
Audio equipment's (e.g. Radio, CD players, Mp3)				
Digital Photo cameras				
Mobile phones				
Data Projection systems				
Television				

Please list if there are other technologies and indicate how often they use

3. How accessible are the following learning resources/tools for you to facilitate your learning?

	Not available	Limited access	Are not accessible for teaching purpose	Free Access
Social Media				
YouTube				
Weblogs				
Social learning communities (Facebook, blogs, netlog, fourm etc.)				
Search engines like Google				
Email				
Chat rooms				
Software				
GeoGebra				
Microsoft mathematics				
Spreadsheets				
Power point slides				

Others please list and indicate how accessible for you.

4. How often have you used the following learning resources/tools in your learning?

	Never	Once or twice per semester	About once every month	At least once per week
Social Media				
YouTube				
Weblogs				
Social learning communities (Facebook, blogs, netlog, forum etc.)				
Search engines like Google				
Email				
Chat rooms				
Software				
GeoGebra				
Microsoft mathematics				
Spreadsheets				
Power point slides				

Others please list and indicate how often you used

1. How would you rate your teacher educators' confidence on using technology in teaching?

- a. No confidence
- b. Low confidence
- c. Good Confidence
- d. Very good confidence

2. How do you rate the importance of technology in teaching?



- a. No importance
- b. Some importance
- c. Great importance
- d. Very great importance

3. From your experience of learning with technology what conclusion can you draw about technology in teaching?

- a. Technology has no contribution to learning
- b. Technology has little contribution to learning
- c. Technology has a high contribution to learning
- d. Technology has a very high contribution to learning

C. Select one level of agreement for each statement to indicate how you feel.

SD = STRONGLY DISAGREE, D = DISAGREE, U = UNDECIDED, A = AGREE, SA = STRONGLY AGREE

I feel confident that I could...	SD	D	U	A	SA
1. Send an e-mail to a friend.					
2. Subscribe to a discussion list.					
3. Create a "nickname" or an "alias" to send e-mail to several people at once.					
4. Send a document as an attachment to an e-mail message.					
5. Keep copies of outgoing messages that I send to others.					
6. Use an Internet search engine (e.g., google, wiki etc) to find Web pages related to mathematical concepts.					
7. Search for and find information on different Web sites.					
8. Create my own World Wide Web home page.					
9. Keep track of Web sites I have visited so that I can return to them later. (An example is using bookmarks).					
10. Find primary sources of information on the Internet that I can use in teaching mathematics.					
11. Use a spreadsheet in learning mathematics like geometry.					
12. Use technologies which can help to learn quadratic equation					
13. Use technologies which can help me to learn mathematics					
14. Use multiple mathematical software in learning mathematical concept.					
15. Save documents in formats so that others can read them if					

they have different word processing programs (e.g., saving Word, ClarisWorks, RTF, or text).					
16. Use computer and software for different purposes like to prepare slides, write assignments etc					

1. In your opinion, what are the challenges to use ICT in learning mathematics?

2. Is there any technological support available for you as pre-service teachers at the college to practice?
If available please describes the kind of support provided?

If not available please list the possible reasons

3. In your opinion, what kind of professional support should be provided for pre-service teachers educators to use ICT into their future teaching?



4. In your opinion, is the practices of teacher educators' use of technologies have influence your future teaching mathematics at primary schools? How? Please explain.

5. Any Additional comments?

I am interested in participating in the following activities about using technology in pre-service teacher education (you can choose more than one):

- | | |
|------------------------------|--------------------------|
| i. An interview | <input type="checkbox"/> |
| ii. A focus group discussion | <input type="checkbox"/> |
| iii. Observation Sessions | <input type="checkbox"/> |

If you choose to participate among one or more of the above, please provide your phone number or email: _____

Thank you!

Appendix H

Final questionnaire for pre-service teachers



QUESTIONNAIRE FOR PRE-SERVICE TEACHERS

The questionnaire is prepared to pre-service teacher to collect your opinion concerning technology integration in the teaching learning process of your current teacher education. The questions invite you to reflect on your habit of using ICT while learning. In addition, it invites you to reflect your opinions concerning your mathematics teacher educators' skill and habit of technology integration in their teaching and on technology, pedagogy and content knowledge.

Please answer each question to the best of your knowledge. Your thoughtfulness and candid responses will be greatly appreciated. Your individual name or identification number will not at any time be associated with your responses. Your responses will be kept completely confidential.

Note: Technology for this study refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc.

Thank you for taking time to complete this questionnaire!

A. Demographic information

1. Campus attending

a. _____

b. _____

2. Gender

a. Female

b. Male

3. Age range

a. 18-22

b. 23-26

c. 27-32

d. 32+

4. Do you have teaching experience?

a. Yes

b. No

5. If your answer for question 4 above is "yes", how many years of teaching experience do you have?

a. 0 - 5

b. 6-10

c. 11- 15

d. Above 15



6. Year in the college

a. First year ☐

b. Second year ☐

B. General Technology use

In the following questions, check (X) in the appropriate box in accordance to the level of the technology use in the teaching learning process mathematics.

1. How often have used the following technological devices while learning mathematics?

	Never	Once twice semester	or per month	About once every month	At least once per week
Personal Computers (Computer Lab)					
Laptops					
Audio equipment's (e.g. Radio, CD players, Mp3)					
Digital Photo cameras					
Mobile phones					
Data Projection systems					
Television					

Please list if there are other technologies and indicate how often they use



2. How often have you used the following learning resources/tools in your learning?

	Never	Once or twice per semester	About once every month	At least once per week
Social Media				
YouTube				
Weblogs				
Social learning communities (Facebook, blogs, netlog, forum etc.)				
Search engines like Google				
Email				
Chat rooms				
Software				
GeoGebra				
Microsoft mathematics				
Spreadsheets				
Power point slides				

Others please list and indicate how often you used

3. Any Additional comments?

Thank you!

Appendix I

Interview questions guidelines for teacher educator and pre-service teacher



INTERVIEW QUESTIONS FOR TEACHER EDUCATORS BEFORE INTERVENTION ACTIVITIES

1. As teacher educator, what do you think are the things that make a teacher educator need to know?
 - a. How do you implement those things in your teaching?
 - b. What teaching methods do you use?
 - c. What importances do give on pedagogical content knowledge (PCK)?
2. What importance do you place on technology in teaching pre-service teachers?
3. What do you think are the challenges to integrating ICT in teaching?
4. What can you say about the availability of ICT/technological tools at the college?
 - a. Does the availability and type of technological tools affect your decision to use technology in teaching?
 - b. How do you use the available technology tools in teaching pre-service mathematics teachers?
5. What, do you feel are important technology competencies for you to effectively use technology in teaching pre-service mathematics teachers?
 - a. How can you evaluate your own competencies in technology integration in teaching pre-service teachers?
 - b. Does this level of technology integration competency you have affect your motivation to use technology in teaching?
 - c. How do you engage your learners to learn by using technology?
 - d. Do you believe that engaging pre-service teachers will have a benefit for them? How?
6. Did the college prepare technology related trainings, workshops or other forms for teacher educators for the purpose of integrating technology into teaching?
 - a. What type were these?
 - b. To extent are workshops or other learning activities about pedagogical use of technology?
 - c. Was it effective, why?
7. What do you know about Technological Pedagogical and Content Knowledge (TPACK) framework?
 - a. How do you use TPACK in your teaching using technology?
8. Have you ever thought of TPACK as a guide to your instruction? , if yes,
 - a. In what ways do you use TPACK?
 - b. How do you explain the relationship among technology, pedagogy and content knowledge for effective teaching?
9. Do you think that your habit of teaching with technology has an influence on pre-service teachers' habit of using technology in teaching? Why? Can you give me an example?
10. What is your future plan of enhancing technology integration for your teaching as well as pre-service teachers' future skills?
11. What do say about the importance of technology coordinators support to use technology in teaching?
12. Anything left to say?

Thank you!

Technology for this study refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc.



INTERVIEW QUESTIONS FOR TEACHER EDUCATORS AFTER INTERVENTION ACTIVITIES

1. What did you think of the lessons you taught with technology integrated?
 - a. What did you like about these lessons?
 - b. What did you dislike about these lessons?
2. What part of the lesson did you believe was most successful? Why?
3. What do you believe was least successful? Why?
4. What technology /software do you believe was most successful? Why?
5. Based on your observations, what do you believe pre-service teachers liked about the technology integrated lessons?
6. Based on your observations, what do you believe pre-service teachers disliked about the ICT integrated lessons?
7. How important was the professional learning workshop for you to use technology in your teaching?
 - a. What were the strong and weak sides of the workshop?
 - b. What suggestions do you have for the workshop?
8. How do you find the weekly discussion with colleagues about your technology integrated teaching?
 - a. Was the discussion important to improving your teaching? In what ways?
 - b. What difficulties do you face during these discussions?
 - c. Do you have suggestions about the team formation?
9. How important was TPACK framework to teaching technology integrated lessons?
 - a. Did it help you to frame your pedagogy? In what ways?
 - b. Did it help you to select technology? In what ways?
 - c. Did it help you to select appropriate technology and pedagogy which fits with a particular content? In what ways?
 - d. How do you explain the relationship among technology, pedagogy and content knowledge for effective teaching?
 - e. How useful was it to have technology coordinators in the workshop with the teacher educators?
10. How feasible do you think it would be to use such a professional development activities to enhance teacher educators' skill of technology integration in their teaching in the future?
 - a. Which part of the process do find very important? Why?
 - b. Which part do you think shall be improved? Why?
 - c. Was the professional development effective in helping teacher educators to use technology in their teaching? In what way?
11. As teacher educator, what do you think are the things that make a teacher educator need to know?
 - a. How do you implement those things in your teaching?
 - b. What teaching methods do you use?
 - c. What importance's do give on pedagogical content knowledge (PCK)?
12. What, do you feel are the important technology competencies for you to properly integrate technology into teaching?
13. What do say about the importance of ICT coordinators support to use technology in teaching?
14. What is your future plan of enhancing technology integration for your teaching as well as pre-service teachers' future skills?

Technology for this study refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc.



15. What is your future plan of enhancing ICT integration into your teaching?
16. Anything left to say?

Thank you!

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INTERVIEW QUESTIONS FOR PRE-SERVICE TEACHERS BEFORE INTERVENTION ACTIVITIES

1. How important to you is learning with technology supported lessons? In what ways?
2. Do you have opportunities to play around with technology while learning mathematics?
 - a. If yes, do you found this helpful? In what way?
 - b. If no, do you think it could be helpful? In what ways?
3. What, do you feel about the importance of technology competencies for teacher educators to effectively use technologies in teaching of pre-service mathematics teachers?
 - a. How do you evaluate teacher educators' competencies in technology integration in mathematics teaching?
 - b. Does this level of technology integration competency affect teacher educators' motivation to use technology in their teaching?
 - c. Can you give an example of when your teacher used technology in a way that helped you learn?
4. What do you think are the factors which influence teacher educators to use technology in their teaching?
5. Do you think that teacher educators' habit of teaching with technology has influence on your future teaching of technology integrated lessons in primary schools? How?
6. Anything left to say?

Thank you!

Technology for this study refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc.



INTERVIEW QUESTIONS FOR PRE-SERVICE TEACHERS AFTER INTERVENTION ACTIVITIES

1. What do you think of technology integrated lessons?
 - a. What did you like about these lessons? Did it help your learning? In what ways?
 - b. What did you dislike about these lessons? Why?
2. Do you have opportunities to play around with technology while learning mathematics after the first interview?
 - a. If yes, do you found this helpful? In what way?
 - b. If no, do you think it could be helpful? In what ways?
3. Have you observed any change in how often teacher educators use technology since the first interview?
 - a. How do you evaluate current teacher educators' competencies in technology integration in mathematics teaching?
 - b. How do you compare teacher educators' competencies before and after intervention activities?
4. Do you think that teacher educators' habit of teaching with technology has influence on your future teaching of technology integrated lessons in primary schools? How?
5. What do you think are the factors which influence teacher educators to use technology in their teaching?
6. Anything left to say?

Thank you!

Technology for this study refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc.



INTERVIEW QUESTIONS FOR THE ICT COORDINATORS BEFORE INTERVENTION ACTIVITIES

1. What kind of support do you provide for teacher educators?
 - a. Do you give pedagogical support to them?
2. What do you feel about the importance of technology competencies for teacher educators to effectively use technology in teaching of pre-service mathematics teachers?
 - a. How do you evaluate teacher educators' competencies in using technology in teaching mathematics? Can you give me example(s)?
 - b. What important things can't they do? Can you give example?
 - c. Does this level of technology integration competency affect teacher educators' motivation to use technology in their teaching?
3. What do you think are the factors influencing teacher educators to use technology in their teaching?
4. What can you say about the availability of ICT/technological tools at the college?
 - a. What kinds of technologies are available in the college?
 - b. How many computers are available?
 - c. What kinds of software are available to teach mathematics?
5. Did the college /department ever prepare technology related trainings, workshops or other forms for teacher educators' for the purpose of integrating technology into teaching?
 - a. Does the training or workshop have themes related to pedagogical use of technology?
 - b. Was it effective in helping teacher educators to use technology in their teaching?
Why?
6. What kind of professional development will help you to help teacher educators to use technology in their teaching?
 - a. Do you know about TPACK?
7. What is your future plan of helping teacher educators' skill of technology integration into teaching?
8. Anything left to say?

Thank you!

Technology for this study refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc.



INTERVIEW QUESTIONS FOR THE ICT COORDINATORS AFTER INTERVENTION ACTIVITIES

1. Have you observed any difference in the habit of teacher educators' use of technology integration between before and after intervention activities?
 - a. How do you evaluate current teacher educators' competencies in technology integration in mathematics teaching?
 - b. How do you compare teacher competencies before and after intervention activities?
 - c. Does this level of technology integration competency affect teacher educators' motivation to use technology in their teaching?
2. How important was the professional learning workshop for teacher educators to use technology in their teaching?
 - a. What were the strong and weak sides of the professional learning workshop?
 - b. What suggestions do you have for the professional learning workshop?
3. How do you evaluate teacher educators' effort to integrate technology in their teaching after the professional workshop?
 - a. How do you see the discussion among them?
 - b. Are they asking you more support for their effort?
 - c. How often are they using the available technologies?
 - d. How do you evaluate their current practices?
4. How important do you think the TPACK framework was for teaching technology integrated lessons for teacher educators?
5. How feasible do you think it would be to use such a professional development activities to enhance teacher educators' skill of technology integration in their teaching?
 - a. How do you evaluate the overall process of the process?
 - b. What kind do you suggest for the future?
6. What did you learn from participating in the professional learning workshop?
7. What is your future plan of helping teacher educators' skill of technology integration into teaching?
8. Anything left to say?

Thank you!

Technology for this study refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc.

Appendix J

Focus group discussion guidelines for teacher educators and pre-service teachers



GROUP DISCUSSION GUIDELINES FOR TEACHER EDUCATORS BEFORE INTERVENTION ACTIVITIES

1. As teacher educator, what do you think are the key things that make a good classroom teacher?
2. What importance do you place on technology in teaching mathematics?
 - a. What can you say about the availability of ICT/technological tools at the college?
 - b. What, do you feel are the important technology competencies for you to properly use technology in teaching pre-service mathematics teachers?
3. What do you think are the challenges to integrating technology in teaching?
4. Did the college ever prepare technology related professional development, workshops for teacher educators for the purpose of integrating technology into teaching?
5. What do you know about Technological Pedagogical and Content Knowledge (TPACK) framework?
 - a. Have you ever think of TPACK as a guide to your instruction? How do you use it?
6. Do you think that your habit of teaching with technology has an influence on pre-service teachers' habit of using technology in teaching in schools? Why? Give example.
7. What should be done in the future to enhance teacher educators' skills to integrate technology in their teaching?
8. Anything left to say?

Thank you!

Technology for this study refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc.



GROUP DISCUSSION GUIDELINES WITH TEACHER EDUCATORS AFTER INTERVENTION ACTIVITIES

1. What did you think of the lessons with technology integrated?
 - a. Based on your observations, what do you believe pre-service teachers liked about the technology integrated lessons?
 - b. Based on your observations, what do you believe pre-service teachers disliked about the technology integrated lessons?
2. How important was the professional learning workshop for you to use technology in your teaching?
 - a. How do you find the discussion with a colleague about your technology integration?
 - b. How feasible do you think it would be to use such professional development activities to enhance teacher educators' skills in integrating technology integration in their teaching?
3. What, do you feel are the important technology competencies for you to properly integrate technology into teaching?
 - a. How important was TPACK framework to teach technology integrated lessons?
4. Do you think that your habit of teaching with technology has influence on pre-service teachers' habit of using technology in teaching? Why? Give an example.
5. What is your future plan to enhancing your skills of technology integrated in teaching?
6. Anything left to say?

Thank you!

Technology for this study refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc.



GROUP DISCUSSION GUIDELINES FOR PRE-SERVICE TEACHERS AFTER INTERVENTION ACTIVITIES

1. What do you think of technology integrated lessons?
 - a. Which did you like most?
 - b. Which did you dislike?
2. Have you observed any difference in the habit of teacher educators' use of technology integration between before and after intervention activities? What differences?
3. Have you had a chance to play around with technologies these days?
4. Do you think that teacher educators' habit of teaching with technology has influence on your future teaching of technology integrated lessons in primary schools? How? Give example.
5. What recommendations would you made to teacher educators' use of technology on lesson for pre-service teachers on the future?
6. Anything left to say?

Thank you!

Technology for this study refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc.

Appendix K
Observation checklist



CLASSROOM OBSERVATION CHECKLIST

Teacher educator code: _____

Lesson Topic: _____

College of Teacher Education: a) _____ b) _____ (✓)

Technology used: _____

Classroom Context Description:

Note: 3=observed; 2 = partly observed and 1=Not observed

		3	2	1	Example of fully/observed or partly observed practice
Specialised Mathematics Knowledge (SMK)					
1	Clearly introduced the topic and learning goals				The teacher educator had sufficient knowledge on the topic and he was on the top of it
2	Sufficient knowledge of the lesson				
3	Demonstrates confident in subject’s concepts related to lesson				
4	Uses appropriate materials in relation to the given lesson being taught				
Specialised Pedagogical Knowledge (SPK)					
5	Engage pre-service teachers in exploring real-world issues and solving authentic problems using teaching resources.				The teacher educator used lecture method using LCD projector as replacement of a board
6	Address the diverse needs of all learners by using learner-centered strategies				
7	Providing equitable access to appropriate resources				
Technological Knowledge (TK)					
8	Teacher demonstrates developed knowledge in selecting				The teacher educator was using PowerPoint as a

	technology skills				technology and partly observed when used efficiently. No technical problem was observed in using the technology
9	Demonstrate fluency in the transfer of the used technology knowledge to new situations				
10	Demonstrate knowledge on effective combination of learning support tools				
Specialised Pedagogical Mathematics Knowledge (SPMK)					
11	Possess the ability to integrate teaching approaches that arouse pre-service teachers' creativity				It was possible to use a different pedagogical approach, which fit with the topic, and involving pre-service teachers but this was not observed in this particular lesson.
12	Apply teaching approaches which gives more authority to pre-service teachers in solving mathematics problem				
Specialised Technological Pedagogical Knowledge (STPK)					
13	Engage pre-service teachers in the pedagogy used in learning activities				The technology selected did not seem fit with lecture method. Learners were simple listeners
14	Use the technology used to help pre-service teachers to collaborate				
Specialised Technological Mathematics Knowledge (STMK)					
15	Clear link between technology and the specialised mathematics knowledge				There was a clear link between pedagogy and content. The animation was inviting and thought provoking
16	Design relevant learning experiences that incorporate the technology used to promote pre-service teachers learning				
17	Introduction of fundamental concepts by technology incorporation				
Specialised Technological And Mathematics Pedagogical Knowledge (STAMPK)					
18	Proper choice of technology in relation to mathematics concept and pedagogy				It was hard to observe on which the technology, pedagogy and the mathematics concept goes in harmony during the lesson to facilitate learning
19	Clearly integrate the components of STAMP to promote creative thinking in pre-service teachers				
20	Apply STAMP to promote pre-service teachers' reflection and to clarify pre-service teachers' conceptual thinking.				



Final Note:

Appendix L

Interview questions guidelines for ICT coordinators



INTERVIEW QUESTIONS FOR THE ICT COORDINATORS BEFORE INTERVENTION ACTIVITIES

1. What kind of support do you provide for teacher educators?
 - a. Do you give pedagogical support to them?
2. What do you feel about the importance of technology competencies for teacher educators to effectively use technology in teaching of pre-service mathematics teachers?
 - a. How do you evaluate teacher educators' competencies in using technology in teaching mathematics? Can you give me example(s)?
 - b. What important things can't they do? Can you give example?
 - c. Does this level of technology integration competency affect teacher educators' motivation to use technology in their teaching?
3. What do you think are the factors influencing teacher educators to use technology in their teaching?
4. What can you say about the availability of ICT/technological tools at the college?
 - a. What kinds of technologies are available in the college?
 - b. How many computers are available?
 - c. What kinds of software are available to teach mathematics?
5. Did the college /department ever prepare technology related trainings, workshops or other forms for teacher educators' for the purpose of integrating technology into teaching?
 - a. Does the training or workshop have themes related to pedagogical use of technology?
 - b. Was it effective in helping teacher educators to use technology in their teaching?
Why?
6. What kind of professional development will help you to help teacher educators to use technology in their teaching?
 - a. Do you know about TPACK?
7. What is your future plan of helping teacher educators' skill of technology integration into teaching?
8. Anything left to say?

Thank you!

Technology for this study refers to digital technologies such as computers, laptops, radio, televisions, mobile phones, software programs, etc.



INTERVIEW QUESTIONS FOR THE ICT COORDINATORS AFTER INTERVENTION ACTIVITIES

1. Have you observed any difference in the habit of teacher educators' use of technology integration between before and after intervention activities?
 - a. How do you evaluate current teacher educators' competencies in technology integration in mathematics teaching?
 - b. How do you compare teacher competencies before and after intervention activities?
 - c. Does this level of technology integration competency affect teacher educators' motivation to use technology in their teaching?
2. How important was the professional learning workshop for teacher educators to use technology in their teaching?
 - a. What were the strong and weak sides of the professional learning workshop?
 - b. What suggestions do you have for the professional learning workshop?
3. How do you evaluate teacher educators' effort to integrate technology in their teaching after the professional workshop?
 - a. How do you see the discussion among them?
 - b. Are they asking you more support for their effort?
 - c. How often are they using the available technologies?
 - d. How do you evaluate their current practices?
4. How important do you think the TPACK framework was for teaching technology integrated lessons for teacher educators?
5. How feasible do you think it would be to use such a professional development activities to enhance teacher educators' skill of technology integration in their teaching?
 - a. How do you evaluate the overall process of the process?
 - b. What kind do you suggest for the future?
6. What did you learn from participating in the professional learning workshop?
7. What is your future plan of helping teacher educators' skill of technology integration into teaching?
8. Anything left to say?

Thank you!

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Appendix M

A sample qualitative data analysis

Question: “In your opinion, what are the challenges to use technology into your teaching of pre-service teachers?”

ID	Text	Sorting	Similarities and differences	Themes	Compare and summarise
1	Lack of the required knowledge and skill, lack of availability of the different technological applications, lack of awareness and experience in using technology is not often common in the college	Lack of require knowledge Lack of awariness Lack of experience Lack of aviability of the different technological	Lack of experience and awareness Lack of ICT resources Lack of the required knowledge	Themes emerged : Lack of experience and awareness Lack of the required knowledge is the other frequently mentioned factor which is commonly	Lack of experience and awareness is mentioned by 7 participants in common Lack of the required knowledge is the other frequently mentioned factor which is commonly
2	First, the technologies are not accessible, second, I have no the required knowledge to use the available technologies as I am not used those technologies before and not ware of it in using in my teaching	Technologies are not accessible Lack of required knowledge Not used before and not aware of it	Lack of ICT resources Lack of the required knowledge Lack of awariness	knowledge Lack of PD programs on pedagogical use of ICT is also another frequently listed factor by 13 participants Lack of ICT resources Others	mentioned by 9 participants Lack of PD programs on pedagogical use of ICT is also another frequently listed factor by 13 participants Lack of ICT resources of resources is listed as a factor by 5 participants There are also 2
3	I am not familiar to use technology in my teaching, insufficient availability of technologies and lack of knowledge and	Not familiar to use technology Insufficient	Lack of awareness and experience		

	support to use technologies	availability of technologies Lack of knowledge Lack of awareness Lack of support to use ICT in teaching	Lack of ICT resources Lack of knowledge Lack of PD programs on pedagogical use of ICT		participants who mentioned other factors including time, students knowledge in ICT
4	I am not aware of using technologies in teaching specific mathematics software and believe has no knowledge to use it. There is no also a professional development activity to use technology in teaching	Not aware to use technologies Has no knowledge Lack of PD for teaching	Lack of experience and awareness Lack of PD programs on pedagogical use of ICT		
5	Resources are not sufficient to use, there are no trainings in relation to technology use in teaching mathematics	Resources are not sufficient Lack of training in relation to technology use in	Lack of ICT resources Lack of PD programs on pedagogical use of ICT		

		teaching			
6	Lack of professional development which enable me to integrate ICT in my teaching , I don't have the experience to use technology (i.e lack of experience and I am not aware about it)	Lack of PD to use ICT in teaching Don't have experience Lack of awareness	Lack of PD programs on pedagogical use of ICT Lack of awareness and experience		
7	Lack of knowledge on how to use technology for teaching for different contents of mathematics and lack of motivation to use in everyday class. In addition, not ever participated in PD sessions which are helpful to use ICt in teaching maths	Lack of knowledge Lack of motivation PD which can help me to use ICT in my teaching	Lack of knowledge Lack of PD programs on pedagogical use of ICT		
8	I have limited skill to use technology in teaching, and there is no associated training, lack of resources is also another challenge	Limited skill to use technology No associated training to use technology in teaching	Lack of knowledge Lack of PD programs on pedagogical use of ICT		

9	I have limited experience and awareness. In addition, there is no PD in relation to using technology in teaching maths. I don't have also the time to use technology actually, it requires more time to organise it	Limited experience and awareness No PD in relation to using technology to teach maths Time to use technology	Lack of awareness and experience Lack of PD programs on pedagogical use of ICT Time to use		
10	Insufficient technologies and lack of knowledge to use technologies as well as lack of pd programs which support to use technology is teaching maths is not provided by the college.	Lack of knowledge Lack of PD program whcu support to use technology in teching maths Insufficient technologies	Lack of knowledge Lack of PD programs on pedagogical use of ICT Lack of ICT resources		
11	Lack of awraness and experience, resource. The type of training we have attended also influenced, we use training to know the technology not to use for teaching	Lack of awareness and experience No training on ICT to use for teaching	Lack of awareness and experience Lack of PD programs on pedagogical use		

			of ICT		
12	I don't have enough knowledge to use technology in teaching and limited experience to use it. Even it is not common to use ICT in teaching mathematics We often participated in PD which support to use particular application not to use for teaching	Don't have enough knowledge Limited experience Not common to use ICT in teaching PD Participate in PD to use ICT in teaching	Lack of knowledge Lack of awareness experience Lack of PD programs on pedagogical use of ICT		
13	Lack of skill to use technologies for teaching, insufficient knowledge of students to use computers. It further preparation to use it which implies you need more time	Lack of skill Insufficient knowledge of students on ICT You need more time	Lack of knowledge Lack of time		
14	One of the basic challenge is systematic training which support to use ICT in teaching. The other challenge is the design of the curriculum. Afterall the practice is not matured in the college	Systematic training to support teching with ICT Design of curriculum The practice is not matured	Lack of PD programs on pedagogical use of ICT Lack of awarbens abd experience		

15	Lack of relevant trainings and awareness and lack of relevant experience to use different softwares	Lack of relevant trainings Lack of awareness and relevant experience on different softwares	Lack of PD programs on pedagogical use of ICT Lack of experience and awareness		
16	Lack of training in utilising technology in teaching, and lack of mathematical laboratories	Lack of training in utilising technology in teaching	Lack of PD programs on pedagogical use of ICT		

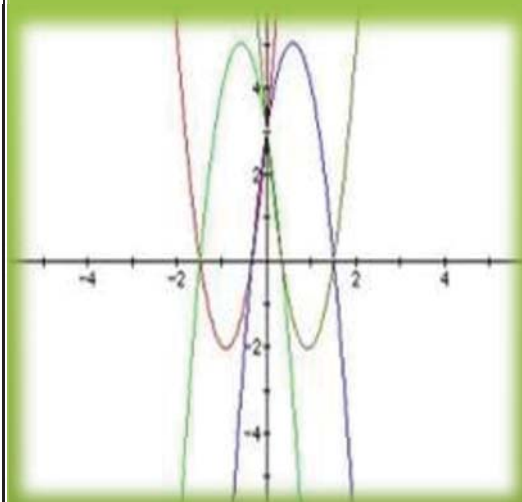
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Themes	N	Description
Lack of experience and awareness	7	Most of them mentioned having no awareness or experience of how to use technology in teaching
Lack of PD programs on pedagogical use of ICT	13	How pedagogy is supported by technology
Lack of the required knowledge	9	Most of them mentioned that they don't have the required knowledge to use ICT in teaching
Lack of ICT resources	5	No software
Others	2	Time constraints

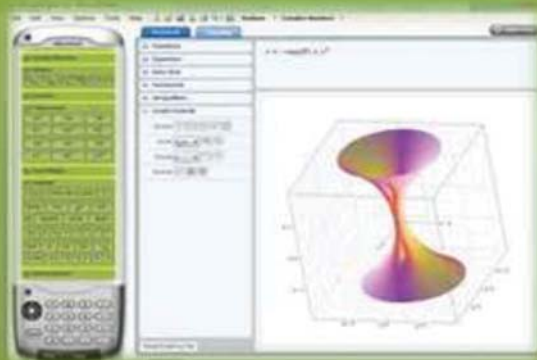
Appendix N

Exemplar material

Technology Integrated Mathematics Teaching



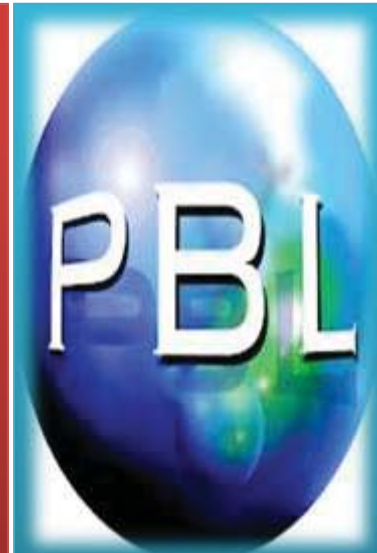
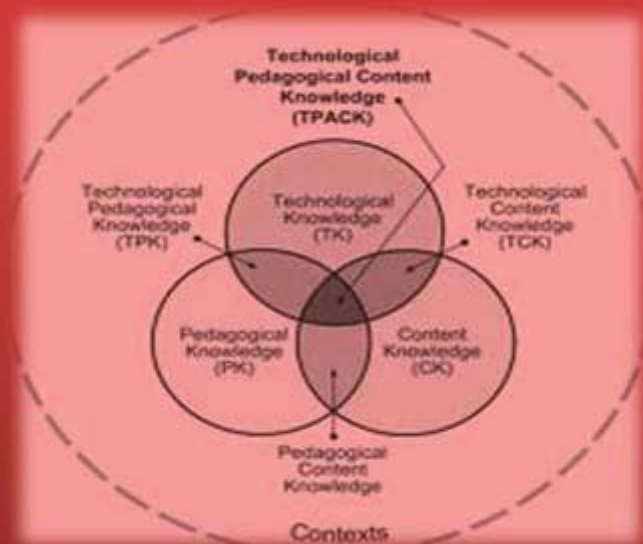
Exemplary Material



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2013



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Introduction

This exemplary material is formulated as a sample for Ethiopian teacher educators to use in their mathematics teaching of pre-service teachers using ICT. The exemplary material is designed to enable teacher educators to encourage them use the available technology in their teaching and facilitate active learning.

The exemplary material considered ICT as a base to deliver the lessons and facilitate the learning activities of pre-service teachers. The use of ICT in this exemplary material also aimed to engage pre-service teachers to understand the implications of ICT in today's society, empowering them to think, supporting them to lead their own learning and career paths and to make the learning activity simple. Finally, a two hours lesson show case is included in the design of this exemplary material.

A constructivist approach of teaching (Problem Based Learning (PBL)) is applied in this exemplary lesson plan design. For the successful delivery of the lesson, a mathematical software called Microsoft mathematics is used to deliver the content. Microsoft Mathematics (<http://www.microsoft.com/education/en-us/teachers/guides/Pages/Mathematics-guide.aspx>) is used to help pre-service teachers with a learning tool and offers a more complete understanding of mathematics. Microsoft Mathematics can help pre-service teachers get the right answers, learn how to solve problems and understand concepts. It's a powerful teaching tool that can be a great benefit in the classroom. Microsoft Mathematics complements the efforts of teachers by helping pre-service teachers visualize, understand, and apply challenging math concepts. Step-by step instructions reinforce key skills in mathematics (e.g., algebra, trigonometry, calculus).

In the exemplary material, assessment and support systems are continuous processes. The assessment involves making expectations explicit and public, setting appropriate criteria and high standards for learning quality and interpreting evidence to determine how well performance matches those objectives set in the lesson.

As a consequence, the ultimate goal of the exemplary material is to teacher educators to help them:

- Use contemporary media application for learning
- Design and develop imaginative ICT based mathematics teaching
- Model for pre-service teachers

Rationale for the exemplary material

The present exemplary material is formulated as a model approach to mathematics teacher educators for technology integrated mathematics teaching. In the exemplary material, appropriate pedagogical learning approach is selected (constructivism manifested through PBL). For the effective delivery of the exemplary material, the pedagogical approaches are supported with ICT use. In addition, continuous support and assessment system is established. An initial framework for the rationale of this exemplary material is indicated in Figure 1.

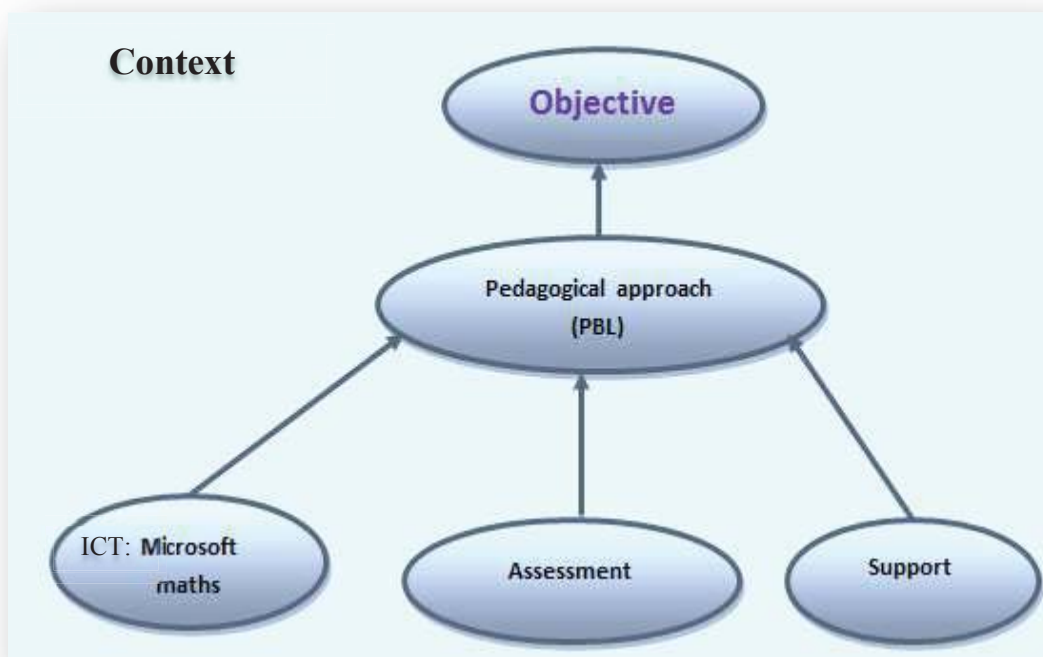


Figure 1. Basis of the design of the exemplary material

The figure implies that the objectives set for each content can be realized through selecting appropriate pedagogical approach. The selected pedagogical approach made effective through the application of ICT integrated with appropriate support and assessment. Each of these issues is explained below.

Stating Objectives

Lesson objectives are useful to clarify the purpose, guide type of pedagogy to be used, assessment, support system and intent of instruction (Panasuk & Todd, 2005). According to Johnson (2000) effective teaching can happen through thoughtful statement of objectives and considering objectives as first key tasks of lesson planning process which leads to create effective lessons and enhance learning. Therefore, this exemplary material considers objective formulation as a basis to think of other components.

Pedagogical Approach

The contemporary researches advocate a more constructivist approach. This exemplary material uses constructivism as a learning approach so that pre-service teachers can i) construct knowledge from their experience, ii) interpret the world with respect to their own experience, iii) actively involve and develop meaning on the basis their experiences, iv) collaboratively work, share multiple idea and negotiate on different perspectives to form meaning v) learn in a realistic settings, and vi) assess their own progress which is adherent with the learning process (Merrill, 1991). The exemplary material uses problem-based learning (PBL) as pedagogical approaches to accomplish constructivism based approach which has six basic steps (Barrett, 2005; Macdonald, 2005) indicated in Figure 2. PBL is aligned with the constructivist framework to make learning and teaching an active and

meaningful inquiry and building of knowledge, skill and attitude by learners (De Simone, 2008). By using this approach pre-service teachers can learn through experimentation and building new information upon the knowledge that they already possessed.

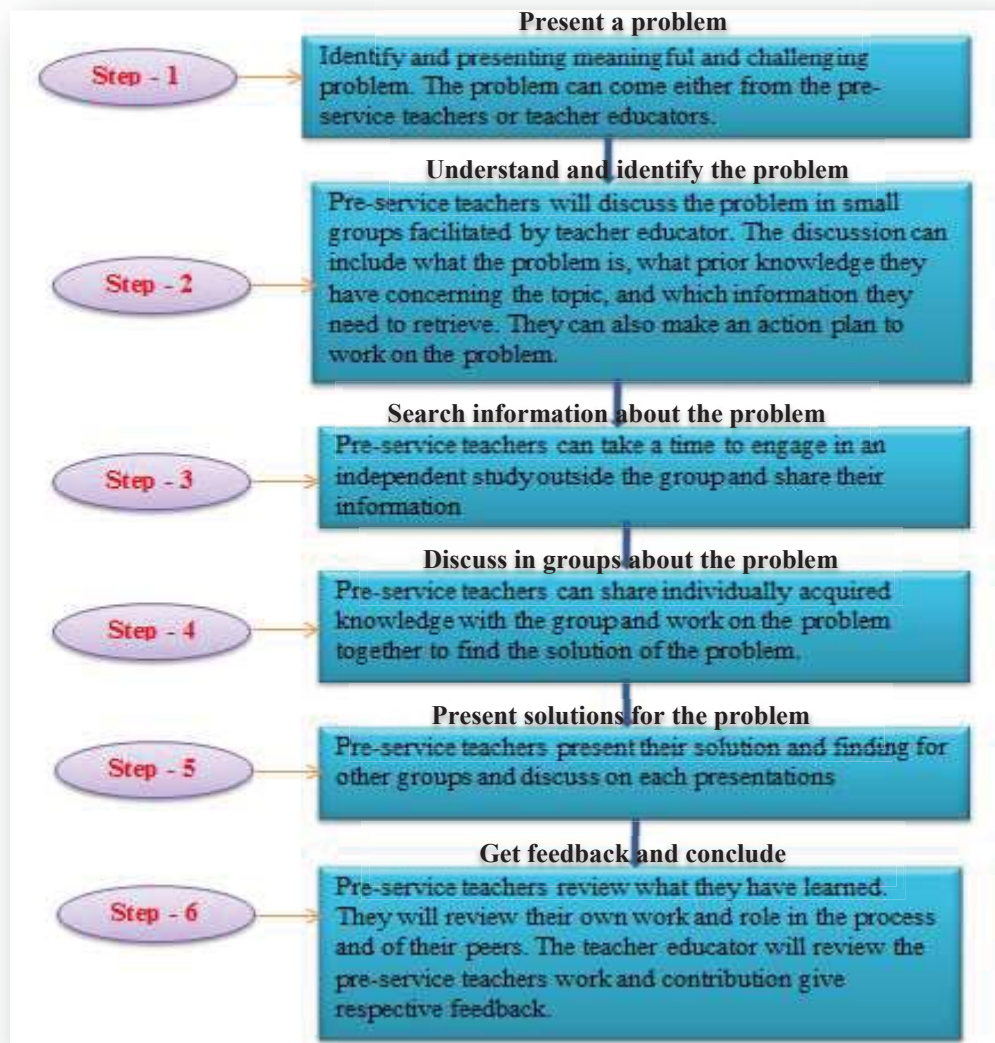


Figure 2. The procedures how to implement PBL

For effective use of PBL, pre-service teachers are encouraged to work collaboratively. The collaboration is enhanced through sharing experience and engaging pre-service teachers in activity about shared problem (Macdonald, 2005). The collaboration can be carried out through the use of ICT applications (in this case Microsoft mathematics). Asking pre-service teachers to explain their understanding and justification and/or supporting evidence about their findings (Bowe, 2005) also facilitates collaboration among pre-service teachers.

Assessment and Support system

The assessment strategy in PBL is integrated into the learning process and continuous so that students would see it as something that is there to help them learn and develop (Macdonald, 2005). Macdonald (2005) listed out sixteen different mechanisms to perform assessment continuously in PBL. These are:

- i) Self-assessment which allows students to think more carefully about what they do and do not know, and what they additionally need to know to solve a problem. This will be done through reflection of each activity so that the teacher can see their progress.
- ii) Peer assessment: this can be done through discussion and reflection with colleagues.
- iii) Reflective, students hand in and receive a feedback.
- iv) Group presentations, students can be asked to take on a role or work within a given problem scenario.
- v) Individual presentations, students are asked to present the components of work they have researched for their contribution to the overall solution of the problem scenario in a group.
- vi) Reports, students would be asked to provide the final product of the problem solution and then the teacher educators will give final feedback of the overall progress.

Hence, for the purpose of this exemplary material, the following assessment methods included are self-assessment, reflection and group presentation. Parallel with each assessment methods there is also a corresponding support system. The support system includes guiding discussion, and giving feedback in each steps of PBL.

Use of ICT

The use of ICT as a learning tool within meaningful contexts of learning can lead to significant educational and pedagogical outcomes and bring major benefits to both learners and teachers (e.g., Ayub, Mokhtar, Luan, & Tarmizi, 2010; Su, 2008; Voogt, 2008). Mathematics education constitutes a privileged subject matter when considering ICT integration to enhance instructional potential and students' active engagement and learning opportunities. There are wide ranges of efficient educational environments and applications available for mathematics education (e.g., Geogebra, Microsoft Mathematics, sage, Maxima, STELLA spreadsheets and databases, etc.) for effective learning. Some of them are free software. The links are indicated below:

- Microsoft Mathematics
<http://www.microsoft.com/education/ww/products/Pages/mathematics.aspx>
- GeoGebra <http://www.geogebra.org/cms/en/download>
- STELLA : <http://www.iseesystems.com/>
- Maxima (for algebra, calculus, graphing and 3D graphing)
<http://maxima.sourceforge.net/screenshots.html>
- PSPP (functionally equivalent to statistics software SPSS, with compatible files).
<http://www.gnu.org/software/pspp/>
- SAGE (this combines many free mathematics programs such as Maxima, into a single package)
<http://www.sagemath.org/>

Hence, ICT is considered in this exemplary material to deliver, facilitate, and manage instruction effectively. The ICT used in this exemplary material is called Microsoft Mathematics.

For effective use of ICT in teaching, teacher educators should have a required knowledge in technology, pedagogy and content. By building on Shulman's formulation of PCK and extending it to teachers' integration of technology into their pedagogy. Mishra and Koehler

(2006) framed “Technological Pedagogical Content Knowledge” (TPACK) as a framework to show the knowledge required from teachers for effective integration of technology in their teaching. The framework has been introduced as a conceptual framework for the knowledge base teachers need to effectively teach with technology. It stems from the notion that technology integration benefits from a careful alignment of content, pedagogy and the potential of technology. The exemplary material uses the framework to explain the knowledge required from teachers to teach technology integrated lessons in the context of mathematics. Each knowledge requirements are explained in Table 1.

Table 1. Knowledge required in teaching mathematics using technology

Components	Definition
Specialised mathematical Knowledge (SMK)	Actual mathematics concepts and specialised mathematics for teaching.
Specialised Pedagogical Knowledge (SPK)	Knowledge of various instructional strategies.
Technology Knowledge (TK)	Various technologies, ranging from low-tech technologies.
Specialised Technological Mathematical Knowledge (STMK)	Teaching effective mathematics cementing the special content knowledge of mathematics with the application of technology.
Specialised Technological Pedagogical Knowledge (STPK)	Anticipating what students are likely to think and find confusing and addressing students thinking using the application of technology
Specialised Pedagogical Mathematical Knowledge (SPMK)	Pedagogical knowledge that fits with the mathematical concepts
Specialised Technological Pedagogical Mathematical Knowledge (STPAMK)	The application of technology for effective mathematics learning of students.

Cotext Considerations

Considering context is important aspect while using ICT in teaching (Koehler & Mishra, 2009). Context can include understanding the pre-service teachers’ prior knowledge on how ICT can be used to build on existing knowledge and the use of the available technologies. The exemplary material is designed based on the context and conditions of Ethiopian Teacher Education Colleges. Table 2 shows the current situations and considerations taken in this exemplary material.

Table 2: Practical considerations in the exemplary material

Conditions	Practical considerations in design of the exemplary material
Less accessibility of internet	<ul style="list-style-type: none"> • Use mathematical software's which doesn't require connectivity • Use of software which are available for free including Microsoft Mathematics and Geogebra.
Large class size with less number of computers	<ul style="list-style-type: none"> • The implementation is based on working in groups • Pre-service teachers are encouraged to work in groups in a computer
Less awareness on ICT integrated lessons	<ul style="list-style-type: none"> • Use of software which doesn't demand advanced skill from both pre-service teachers and teacher educators.
Limited access for mathematical software's	<ul style="list-style-type: none"> • Some mathematical software is arranged by the researcher and the software selected for this exemplary material is free. In addition, this exemplary material is aimed at designing lesson with the available resources.
Alignment with interest of the school policy	<ul style="list-style-type: none"> • The Ethiopian Teacher Education Colleges are encourages to use the available ICT's in the teaching learning process.

Specific Example of an Instructional Process (Show Case)

The show case is designed based on the above underpinning theoretical framework. It is designed based on a pre-determined technology and method of teaching.

Overview of the lesson and its requirement

Lesson topic: Graph of the equation of the form $y = ax^2 + bx + c$

Type: 2 hours lesson

Location: In the computer lab

Technology used: Microsoft mathematics.

Resources required

- Computers
- A software called Microsoft mathematics

Minimal technical Skills for Success

Teacher Educators:

- Basic computer skills

- Use of the mathematics software called Microsoft mathematics
- Knowledge required in teaching mathematics using technology (see Appendix 1)

Pre-service teachers:

- Basic computer skill
- Basic knowledge to use Microsoft mathematics

Minimum Software Requirements Lesson

- Microsoft mathematics software

Lesson Description

This lesson is designed based on the objective that pre-service teachers clearly know the shape and the characteristics of the graph of any quadratic equation. Hence, at the end of the lesson pre-service teachers will be able to:

- Understand the concept of graph of the equation of the form $y = ax^2 + bx + c$
- Identify the characteristics of the graph of the form $y = ax^2 + bx + c$ when a, b and c are varied.
- Draw the graph of an equation with the form $y = ax^2 + bx + c$

The overall activities in the framework are explicitly explained in Table 2 as a general overview of instruction. The table aimed to show what activities are expected from both the teacher educators and pre-service teachers, how each activity can be supported using Microsoft mathematics to achieve the intended results through the six steps of PBL.

Table 2: General overview of the instruction process based on the steps of PBL

What?			How?		Why?
Steps (PBL)	Activities		Assessment and support	Using Technology	
	Teacher educators	Pre-service teachers			
1	<ul style="list-style-type: none">- State objectives- Find out meaningful problem- Introduce the problem	<p>Pre-service teachers figure out the problem</p> <ul style="list-style-type: none">- Try to find out pre-hand information- Gather relevant information and ready for group discussion	<p>Make available the necessary resources as reference material</p> <p>Self-assessment which allows thinking more carefully about what they do and do not know related with the problem.</p>	<p>The teacher educator invites pre-service teachers to open Microsoft Mathematics.</p>	<p>Expected competency</p> <p>Facilitate group working and familiar in using Microsoft Mathematics.</p>
2	<p>Guide pre-service teachers based on their demand</p> <ul style="list-style-type: none">- Give practical example & additional reading materials- Evaluate pre-service teachers structured plan and give feedback	<p>Pre-service teachers form a group and discuss the outlined problem.</p> <ul style="list-style-type: none">- Sharing experience related to the problem- Evaluate the given practical examples and investigate additional information	<p>Using a checklist the teacher identify resources based on pre-service teachers need (examples, and related literatures)</p>	<p>The discussion can start about the graph in selecting intervals of a, b and c to change.</p>	<p>Relate their prior knowledge with the real and existing situations.</p>
3	<p>Guide pre-service teachers activities and check up their progress</p>	<ul style="list-style-type: none">- Share tasks individually- Independently explore needed information for the problem- Come up with concrete idea/ proposal for group discussion	<p>Provide ongoing opportunities for pre-service teachers to articulate what they are learning in their groups by asking probing questions and reflection.</p>	<p>Use the characteristics of the graph based on the observed result from computer output to verify their opinion and discussion points</p>	<ul style="list-style-type: none">- develop self-directed learning- Familiar with data exploration and proposal preparation
4		<ul style="list-style-type: none">- Share their newly	<p>The teacher can support the</p>	<p>See the characteristics of the</p>	<ul style="list-style-type: none">- sharing

	<ul style="list-style-type: none"> - Facilitate the group discussion - Give feedback based on the groups proposed solution 	<p>acquired knowledge within the group</p> <ul style="list-style-type: none"> - Work on the problem and come up with concrete solution 	<p>discussion through the use of the results observed from the computer.</p> <p>The ongoing progress can be accessed via group presentations, pre-service teachers can be asked to take questions to discuss on the suggested solutions.</p>	graph animating a, b and c	<p>cognitions to solve existing problems in groups</p> <ul style="list-style-type: none"> - capable on problem analysis and concert solution proposal
5	<ul style="list-style-type: none"> - Follow up the presentation 	<ul style="list-style-type: none"> - Finalize their group assignment based on the teacher educators' feedback - Present their final product for the whole group 	<p>Facilitate their group discussion.</p> <p>Pre-service teachers are asked to present the components of the work they have researched to the overall solution of the problem scenario. In this case each pre-service teacher expected to contribute for the presentations.</p>	They can show for group members through projection system what happen on the graph when a, b and c are animated and their general conclusion	<ul style="list-style-type: none"> - Develop skill, knowledge and attitude to solve an existing problem. In this case what is the characteristics of the graph when a, b and c are animated.
6	<ul style="list-style-type: none"> - The teacher educator review pre-service teachers' final work. - Give constructive feedback and evaluation 	<ul style="list-style-type: none"> - Share different views and solutions from other group including teacher educators feedback and review their conclusion - Analyse what they have learned so far. 	<p>Pre-service teachers would be asked to provide the final product of the problem solution and then the teacher give final feedback of the overall progress</p>	Discuss the concluding remark showed on the graph	<ul style="list-style-type: none"> - Become confident to solve existing problems by the application of Microsoft Mathematics

Note that the teacher educators are advised to prepare a checklist that can help to assess pre-service teachers' work during each phase of the problem-solving process.

Application of Microsoft Mathematics in PBL instruction (Show case).

The next section explains the practical application of Microsoft Mathematics during the problem based learning of the selected instruction. The show case illustrates the functions of Microsoft mathematics to handle some mathematical concepts and how all the six PBL steps can be supported by them.

Step - 1: Present a problem

A teacher educator states a relevant problem based on the pre-service teachers context. The teacher educator invites pre-service teachers for discussion through changing a, b and c and observe the effect. The problem could be “illustrate the characteristics of the graph of any quadratic equation of the form $y = ax^2 + bx + c$ as a, b and c are varied.” Microsoft Mathematics software will be used to illustrate. A screen shoot from Microsoft mathematics is shown in Figure 3.

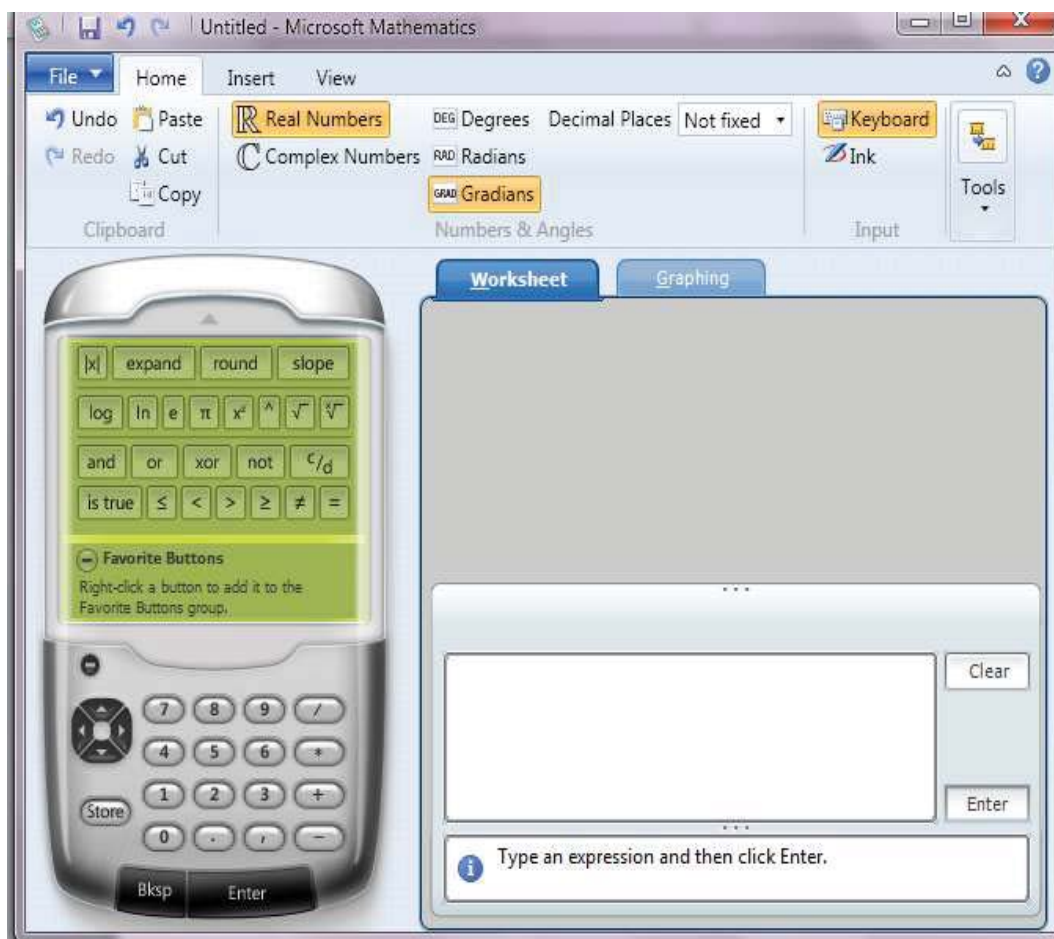


Figure 3. Microsoft Mathematics 4.0 interface

Step - 2: Understand and identify the problem

Pre-service teachers discuss about the problem in small group guided by the teacher educator. The discussion within their small group can be possible come out with the possibilities of different graphs as the values changes. The variables that can be changed are indicated in Figure 4.

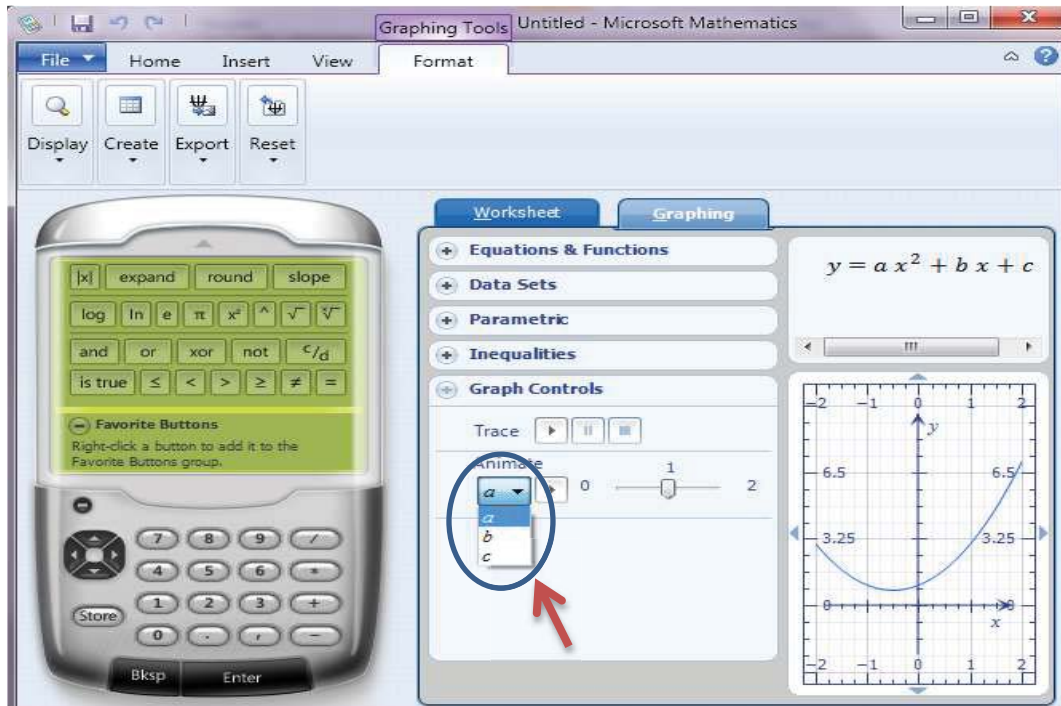
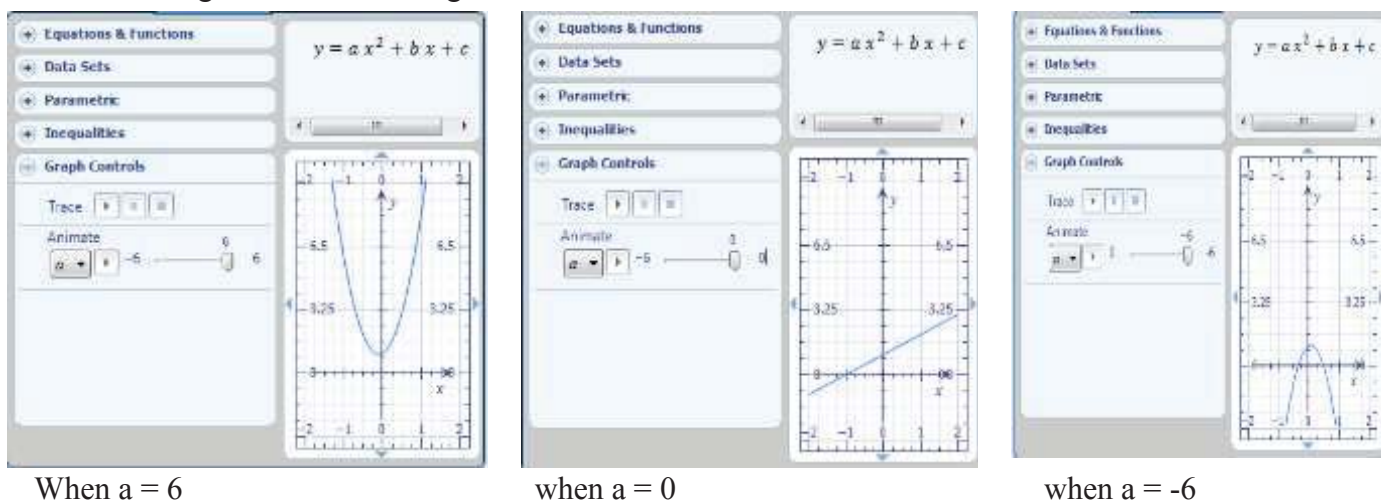


Figure 4. The variable in Microsoft Mathematics which determine characteristics of graphs

Step - 3: Search information about the problem

Now the pre-service teachers are engaged to find out their solution based on the outlined problem which was brain stormed during small group discussion in step two. This is the time pre-service teachers can see different shapes of the graph as a, b and c are animated. Example is shown in Figure 6 when a changes.



When a = 6

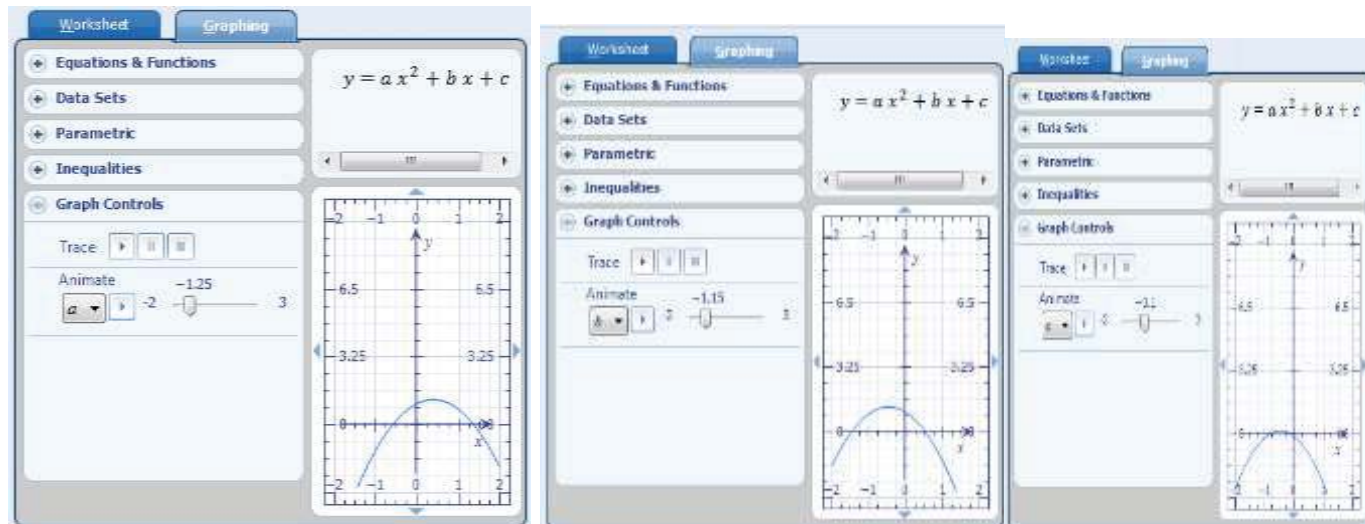
when a = 0

when a = -6

Figure 5. The shape of graph of $y = ax^2 + bx + c$ when a = 6, 0 and -6

Step - 4: Discuss in groups about the problem

Again the discussion starts through in groups where every pre-service teacher will come up with their proposed solutions investigated during step three. Each proposal can be tasted against the application of the software. For example a pre-service teacher could say the graph will bend down ward when the value of a move from -2 to 3 or as b or c changes what will happen to the graph. In this case pre-service teachers can check the shape of the graph based on the proposal.



When $-2 < a < 3$

When $-2 < b < 3$

When $-2 < c < 3$

Figure 6: The shapes of the graph when a , b and c are varied on Microsoft mathematics

Step - 5: Present solutions for the problem

In this step, pre-service teachers in group present their findings to the teacher educator and other groups also attend the presentation. Through the discussion, every pre-service teacher and the course teacher educator can reflect their idea.



Figure 7. Presentation on LCD projector

Step - 6: Get feedback and conclude

Finally, pre-service teachers submit their complete assignment and the teacher educators will give them feedback (evaluation result).

Note:

Teacher educators can also use a lesson plan format attached (see Appendix 2) if they are interested to use to prepare technology integrated lesson plan.

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Appendix 1

The following basic knowledge requirements are demanded from teachers to teach mathematics using Microsoft Mathematics 4.0.

SMK: The basic knowledge, principles about the graphs of quadratic equations ($y = ax^2 + bx + c$) and forecasting errors and misconceptions of students while learning graph of quadratic equation and solving the errors and misconception with new structure. For example, there is often over generalisation about a shape and position of the equation regardless of the value of a, b and c ($y = ax^2 + bx + c$).

SPK: The knowledge of teaching about graphs of quadratic equations through anticipating what students are likely to think and what they will find confusing and how the PBL method is designed for students learning this content including how it can minimise students' confusion. The teacher may decide that grouping students and challenging them to find out what happen when the values of a, b and c in the equation $y = ax^2 + bx + c$ are varied is an appropriate approach.

TK: Involves the skills required to operate Microsoft mathematics 4.0. For example, a teacher should know how to draw the graph, save the result and change the shape and position of the graph. It includes understanding level of students' skill in using Microsoft mathematics to clear understanding of the concepts of graph of quadratic equation ($y = ax^2 + bx + c$).

SPMK: This is the knowledge of teachers' understanding of students' misconceptions and what students will find confusing related to the concept of graph of quadratic equation of the form $y = ax^2 + bx + c$ and teaching them with appropriate PBL methods.

STMK: It is related with understanding different ways of interpreting students understanding of graph of a quadratic equation of the form $y = ax^2 + bx + c$ and ways to facilitates students learning by using Microsoft mathematics 4.

STPK: It is concerned with knowing how PBL method and how it is enhanced as a result of the availability of Microsoft mathematics 4. This includes an understanding of the importance of Microsoft mathematics 4 in teaching graph of quadratic equation, and knowledge of PBL. Students can be impressed while solving the problem by the use of Microsoft mathematics while seeing different shapes and positions of the graph as "a" and "b" are changing in the equation $y = ax^2 + bx + c$.

STPAMK: It is the knowledge of the application of Microsoft mathematics 4 for effective learning a graph of quadratic equation ($y = ax^2 + bx + c$) of students through teaching method called PBL. This requires the skill of using Microsoft mathematics 4, understanding students' misconceptions about area a rectangle and sizing up the misconceptions. It also includes understanding of the instructional advantage of PBL and combing all these knowledge and use in the classroom for effective teaching graph of quadratic equation ($y = ax^2 + bx + c$).

Appendix 2

Contents

The following components are intended to be included in the proposed professional learning workshops.

Professional Learning Workshop - One

- The importance of ICT on teaching
- The concept of TPACK
- ICT integrated lesson design
- Importance of context on ICT integration
- The importance of team work on PD
- Introduce some mathematical software including
 - Microsoft Mathematics
 - Geogebra
 - Maxima
- Use of ICT based exemplary material (lesson based on a particular mathematical software) – Microsoft Mathematics
- Contextual issues will be included based on the context analyses

Professional Learning Workshop – Two

This workshop will be entirely evaluation of the whole process of the PD. The following issues will be addressed in the workshop.

- The challenges on ICT integration process
- The impact of the PD happened
- Benefits of the PD happened
- The importance of team work
- Drawbacks of the PD that should be improved
- Strong sides of the PD
- Contextual issues will be included as the PD goes on.

Program Schedule and Contents of the Professional Learning workshop

Professional Learning Workshop One					
Contents	Time	Activity	Facilitator	Required material	Note
The importance of ICT on teaching					
The concept of TPACK					
ICT integrated lesson design					
Importance of context on ICT integration					
The importance of team work on PD					
Introduce some mathematical software including					
○ Microsoft Mathematics					
○ Geogebra					
○ Maxima					
Use of ICT based exemplary material					
Contextual issues will be included based on the context analyses					
Professional Learning Workshop Two					
The challenges on ICT integration process					
The impact of the PD happened					
Benefits of the PD happened					
The importance of team work					
Drawbacks of the PD that should be improved					
Strong sides of the PD					
Contextual issues will be included as the PD goes on					

Evaluative workshop at the end of the program

This workshop will be takes place at the end of the program. The workshop will be held in which the two college mathematics teacher educators will meet together and share their experiences and evaluate the program as a whole.

Workshop objectives

At the end of the workshop, you (participants) are expected to:

- Share good practices of implementation of collaborative professional development in ICT integration into teaching
- Explain your positive gains of in terms your beliefs, knowledge and skills as the result of implementation of the collaborative professional developments as well as ICT integration into teaching
- Describe changes in pre-service teachers' interest and motivation to use ICT into their future teaching
- List challenges faced during the implementation of ICT integration into teaching as well as the collaborative professional development process.
- Suggest strategies to overcome the challenges faced during the process
- Put strategies for the continuity of the program within the colleges as well as selling the program into other similar colleges in the regions.

Evaluation of the teachers' implementation of the program ideas

The following questions are formulated to lead the evaluation

1. What good practices have you experienced during the implementation of program ideas in classroom? (What have you gained in terms of beliefs, knowledge, skills of ICT integration into teaching)?
2. What changes have you observed in pre-service teacher motivation and interest when you implement the program ideas in the classroom?
3. What challenges have you encountered while implementing the program ideas in classroom teaching practices?
4. What measures do you suggest to overcome the challenges and to improve the implementation?
5. What do you suggest for the continuity of the program in the colleges?

Appendix O

A sample completed observation checklist using projector before the PD program

CLASSROOM OBSERVATION CHECKLIST

Teacher educator code: DM- 1 (TE1)

Lesson Topic: Definition of increasing and decreasing functions

College of Teacher Education: a) College 1 b) College 2 (v)

The technology used: LCD projector was used in the entire lesson

Classroom Context Description:

There were 32 pre-service teachers during the lesson which lasts for 60 minutes. The teacher educator was using an LCD projector to display data and the graphs. The teacher educator started the lesson by defining increasing and decreasing function.

The pre-service teachers were attending the lesson watching the slides. Some of the slides were helped pre-service teachers to attend the lesson actively as there were some animation components. For example, the teacher educator showed the increasing and decreasing function on the slide accompanied with some animated functions. It seemed pre-service teachers were motivated by the animated graphs.

Note: 3=observed; 2 = partly observed and 1=Not observed

		1	2	3	Example of fully/observed or partly observed practice
Specialised Mathematics Knowledge (SMK)					
1	Clearly introduced the topic and learning goals			✓	The teacher educator had sufficient knowledge on the topic and he was on the top of it
2	Sufficient knowledge of the lesson			✓	
3	Demonstrates confident in subject's concepts related to the lesson			✓	
4	Uses appropriate materials in relation to the given lesson being taught		✓		
Mode = 3					
Specialised Pedagogical Knowledge (SPK)					
5	Engage pre-service teachers in exploring real-world issues and solving authentic problems using teaching resources.		✓		The teacher educator used the lecture method using an LCD projector as replacement of a board

6	Address the diverse needs of all learners by using learner-centered strategies		✓		
7	Providing equitable access to appropriate resources	✓			
Mode = 2					
Technological Knowledge (TK)					
8	Teacher educator demonstrates developed knowledge in selecting technology skills		✓		The teacher educator was using PowerPoint as a technology and partly observed when used efficiently. No technical problem was observed using the technology
9	Demonstrate fluency in the transfer of the used technology knowledge to new situations		✓		
10	Demonstrate knowledge on the effective combination of learning support tools		✓		
Mode = 2					
Specialised Pedagogical Mathematics Knowledge (SPMK)					
11	Possess the ability to integrate teaching approaches that arouse pre-service teachers' creativity		✓		It was possible to use a different pedagogical approach, which fit with the topic, and involving pre-service teachers , but this was not observed in this particular lesson.
12	Apply teaching approaches which give more authority to pre-service teachers in solving the subject problem	✓			
Mode = both 2 and 1					
Specialised Technological Pedagogical Knowledge (STPK)					
13	Engage pre-service teachers in the pedagogy used in learning activities	✓			The technology selected did not seem fitting with lecture method. Learners were simple listeners
14	Use the technology used to help pre-service teachers to collaborate	✓			
Mode = 1					
Specialised Technological Mathematics Knowledge (STMK)					
15	Clear link between technology and the specialised mathematics			✓	There was a clear link between pedagogy and content. The animation was inviting and

	knowledge				thought provoking
16	Design relevant learning experiences that incorporate the technology used to promote pre-service teachers learning			✓	
17	Introduction of fundamental concepts by technology incorporation			✓	
Mode = 3					
Specialised Technological And Mathematics Pedagogical Knowledge (STAMPK)					
18	Proper choice of technology in relation to mathematics concept and pedagogy	✓			It was hard to observe on which the technology, pedagogy and the mathematics concept go in harmony during the lesson to facilitate learning
19	Clearly integrate the components of STAMP to promote creative thinking in pre-service teachers	✓			
20	Apply STAMP to promote pre-service teachers' reflection and to clarify pre-service teachers' conceptual thinking.	✓			
Mode = 1					

Final Note:

Even though pre-service teachers were not involved in the process, the lesson was though provoking and interesting with minimal technology use.

Appendix P

Completed observation result of the teacher educators after the PD program

STAMPK Constructs		N			Mode	Observed Practices
		1	2	3		
Specialised Mathematics Knowledge (SMK)						
1	Clearly introduced the topic and learning goals			12	3	All of the teacher educators were able to explain the concepts consistently and clear in each lesson.
2	Sufficient knowledge of the lesson			12	3	
3	Demonstrates confident in subject's concepts related to lesson			12	3	
4	Uses appropriate materials in relation to the given lesson being taught	1	11		3	
Specialised Pedagogical Knowledge (SPK)						
5	Engage pre-service teachers in exploring real-world issues and solving authentic problems using teaching resources.	4	8		3	Most teacher educators supported pre-service teachers to engage in the lesson through asking and supporting each pre-service teacher requiring help
6	Address the diverse needs of all learners by using learner-centred strategies	6	6		3	
7	Providing equitable access to appropriate resources	6	6		-	
Technological Knowledge (TK)						
8	Teacher demonstrates developed knowledge in selecting technology skills	4	8		3	The selected ICT in each lesson was use by teacher educators though there were some challenges on the side of pre-service teachers. For example, some pre-service teachers had the technical problem in using some software like Geogebra
9	Demonstrate fluency in the transfer of the used technology knowledge to new situations	6	6		-	
10	Demonstrate knowledge on effective combination of learning support tools	8	4		2	
Specialised Pedagogical Mathematics Knowledge (SPMK)						
11	Possess the ability to integrate teaching approaches that arouse pre-service teachers'	2	10		3	The pedagogy selected by most teacher educators supported pre-service teachers to understand the

12	creativity Apply teaching approaches which gives more authority to pre-service teachers in solving the subject problem	4	8	3	mathematical concept on board during the lesson.
Specialised Technological Pedagogical Knowledge (STPK)					
13	Engage pre-service teachers in the pedagogy used in learning activities	4	8	3	Most teacher educators picked the readily available ICT, which could support their respective pedagogy used.
14	Use the technology used to help pre-service teachers to collaborate	4	8	3	
Specialised Technological Mathematics Knowledge (STMK)					
15	Clear link between technology and the specialised mathematics knowledge	2	10	3	In most of the lesson, it was observed that the selected ICT was supported pre-service teachers to understand the mathematics concept issued during the lessons
16	Design relevant learning experiences that incorporate the technology used to promote pre-service teachers learning	6	6	3	
17	Introduction of fundamental concepts by technology incorporation	6	6	-	
Specialised Technological And Mathematics Pedagogical Knowledge (STAMPK)					
18	Proper choice of technology in relation to mathematics concept and pedagogy	4	8	3	Teacher educators were observed challenged to select the appropriate technology that fits with the mathematical concept to be delivered in the classroom and the pedagogy selected. It is observed, however, most of the lesson were engaging and active
19	Clearly integrate the components of STAMP to promote creative thinking in pre-service teachers	6	6	3	
20	Apply STAMP to promote pre-service teachers' reflection and to clarify pre-service teachers' conceptual thinking.	8	4	2	